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Vol. 30 May, 1938 No. 5

THE WATER WORKS EXECUTIVE AND HIS COMMUNITY

HIS PLACE IN A THREE BATH-ROOM ERA

BY RALPH COONEY

The modern city, as we know it, owes its existence to the fact that you can flush a toilet on the tenth floor of a hotel or an apartment house or an office building—and, in the normal course of events—achieve satisfactory results.

So completely has this interesting phenomenon—and it is an interesting phenomenon—become a part of our daily lives that those who are steeped in the culture and tradition—and gore—of the old world across the Atlantic scornfully refer to ours as a Bath-Room Civilization.

Having spent a few days during the past winter in a New England farm-house unencumbered with modern plumbing, I, for one, am quite willing to accept the aesthetic damnation of our European friends. My own brand of cultural growth seems to flower better among the comforts which you gentlemen are laboring to provide for me.

I have no intention of boring you further with autobiographical reflections. The fact that I, as an individual, have become used to the conveniences of the various utility services at my command is quite unimportant. But the fact that millions of my and your fellow citizens are coming to take such conveniences for granted—that they are basing their whole system of living upon the stable performance of utility systems—is a matter of very considerable

An address given at the New Orleans convention, April, 1938 by Ralph Cooney, Advertising and Promotion Manager, Bing and Bing, Inc., New York, N. Y.

concern to every man engaged in the business of providing the public with services of this nature.

Whether the man responsible for the operation of a utility service acts in the name of a private enterprise or whether he functions as a representative of government, he stands at a nerve-center of our social and economic life. The consequences of his activities reach far beyond the circle of responsibilities directly associated with his job.

I feel reasonably sure that I am not pulling any rabbit out of the hat in making this observation. You, of all people, must carry this realization deep in your hearts at all times. You must know it much better than I ever can.

Yet here I am, barging into your discussions, and talking about certain aspects of this very vital business of yours. Why?

First, because I think I have a right to do so. I am a creature of the forces you manipulate. You made me what I am today. And second, because I know that in every man's job—in my own job—the details pile up and pile up to a point where broad objectives become obscured. Talking to you, I am blissfully unaware of the thousand and one things that clutter up your daily task. Perhaps, therefore, I can give you a picture of some of the activities which would help me, as a citizen, appreciate your work better. Perhaps, by optimistically over-simplifying your whole problem, I can help you forget some of the little things that clutter up the scenery.

We have been very busy during the past half-century—busy building a way of living wholly dependent upon the continued and efficient functioning of a group of basic public services.

We have put people to work in many-storied office buildings, because we have believed that elevators would continue to function, that lights would continue to burn and faucets continue to produce water. We have built homes without coal bins, without kitchen chimneys and without wells because we have come to feel that our utilities will constantly provide the essential services which make these facilities no longer necessary.

We have created a business technique based upon the rapid interchange of information by telephone, telegraph and radio. We have developed great commercial districts because rapid transit services have enabled us to move large masses of people back and forth daily.

We have gambled our lives on the conviction that, despite the thousand contaminations which cities breed, the water which comes into our homes is of unfailing purity.

We have gambled our lives—and our property—on the faith that the supply of water back of those red and yellow hydrants along the curb is sufficiently stable at all times to guarantee victory over the ever-present menace of fire.

We have been creating a new way of living—a new system of society. We have been creating a Utility Civilization.

And, as is usually the case, we haven't realized just what we have been doing—either to our social organism or to ourselves. New social orders do not come into being overnight. And they do not come into being because some super-mind wakes up some morning, squints with disgust at the world about him, and says "Presto-Changeo, Mumbo-Jumbo—New Social Order—Take it away and see how it works!"

Visions of change undoubtedly come to many thinking men—but the actual accomplishment creeps up on us. Great revolutions—dramatic as they may appear—are but the culmination of years of slow fermentation in the mass mind.

Today, we have come to realize that the word "revolution" does not necessarily connote an exchange of gunfire between the embattled citizenry and the king's henchmen. We recognize the true nature of the great change in working methods which occurred in the early part of the nineteenth century and correctly label it as the Industrial Revolution.

But this is not enough.

If we give thought to the matter, we will see that the Industrial Revolution is only a phase of a greater revolution which is gradually changing the individual from a self-sufficient, self-supporting entity into an increasingly dependent cell in a great system.

The Industrial Revolution made the average man economically dependent. Our Utility Revolution is making him physically dependent, as well. From a hewer of wood and a drawer of water, he is fast becoming a pusher of buttons and a turner of faucets. And with the progress achieved already in the use of the photo-electric cell, it is quite possible that even these slight physical exertions may be eliminated.

At the same time, his mental horizon is widening. Thanks to this same utility civilization, he knows the news of the world almost as

soon as it happens, he hears the words of his nation's leaders even as they are spoken, he has only to go to his local movie to see re-enacted before him scenes of world-shaking consequence.

All the services and facilities at his command are taken pretty much for granted. He has forgotten the days when he went without them. Chances are that he is young enough not to have known a day when most of them were not available. They are as natural to him as the wind and the rain—and if he lives in some of our industrial cities—they are apt to be more natural than the sun itself.

But—as this combination of increasing physical dependence and increasing mental stimulus continues something is going to happen. I have no idea what this precise something will be—and I am not going to indulge in the pleasant whimsey of depicting imaginary catastrophes—but some event, or series of events is going to occur, some situation or series of situations is going to arise which will haul this whole utility civilization of ours before the court of public opinion.

The public has become educated to live by the utility services at its command—it enjoys them—it reaches out for each new labor-saving device as it comes along. But it has only the vaguest idea of the mechanics of operation and distribution by which these utility services are made available. And, by the same token, it looks upon the men who direct these services and their operation as slightly mysterious creatures.

As long as all goes well, it may be argued that such an attitude on the part of the public is quite as satisfactory as any other. But—in the presence of an agitating influence—mystery invites attack!

The public is all of us—you and me and the fellow down the street. Each of us is busy with his own affairs—earning a living, courting a girl, nursing a hang-over, worrying over little Willie's tonsils. Very few of us go around consciously remembering that we are part of this great something called the public.

We read in our newspapers every day accounts of what the public wants and what the public ought to have and how the public should support this or oppose that. Nine times out of ten, we fail to realize that this "public" that's talked about so constantly really means us!

But the tenth time—that's different! We've just paid a tax that seems particularly unjust. Or a piece of legislation has been proposed that looks bad for our business. Or the drinking water has smelled funny for a couple of days!

We air our views to the next door neighbor. We exchange opinions with a man on the bus and are gratified to learn that he agrees with us. We kick to the fellows at the office. We get the members of our luncheon club to start talking. Somebody introduces a resolution of protest, and the reporters present include a mention of this fact in their stories. An ambitious young lawyer, looking for a chance to get in the public eye, makes a speech on the subject.

And the first thing we know the headlines begin to appear—"Public Protests Tax on Ping Pong Balls," "Public Aroused Over Pending Auto-Trailer Bill," "Public Demands Clean-Up in City Waterworks."

Sometimes, however, the chain of events doesn't work out this way—we, as individuals start out with our gripe, but somewhere along the line we get a different point of view. We meet a fellow who shows us that the tax is justified. Or who makes us realize that the proposed law does have some merit. Or who reminds us that the little odor in the water comes from a simple, explainable cause—and, anyway, will be out of the city system by tomorrow!

And we go back to our bread-winning, our courting, our hangover-nursing and our worrying over Willie—until the next time!

The public acts as the public only when a sufficient number of individuals are moved to think along the same general lines. It takes a considerable jolt to start such a mass movement—but once started, it gains momentum at a tremendous rate of speed. Once under way, it can rarely be halted short of its objective!

Every man engaged in the job of supplying a basic public service must have—not in the back—but in the front of his mind—a clear understanding of this force and how it works. He must face the realization that he is in a particularly vulnerable position—because the services supplied under his direction affect the daily lives of all of his fellow citizens all the time.

How can you who are in this position make that position stronger?

There is only one sure way. That is by educating as many of the individuals as you can reach in your particular public—educating them, first, to a more complete and more sympathetic understanding of the way your survice functions—and second, to a conviction that you (and the men who work with you) appreciate the solemn nature of your obligation to them and are devoting your best thought and your full energy to the community's good.

Your objective must be to create, within the ranks of your public, an influential percentage who will realize that the "smelly water"—

and by this phrase I mean all the problems that may arise in your business—is receiving intelligent attention from experts fully cognizant of their public responsibility. You need men and women, boys and girls, who will not only know better than to start adverse waves of public opinion, but who will also be sufficiently informed and sufficiently sympathetic to nip quickly the rumblings of their less informed neighbors.

In making this charge to you, I am quite aware of the one great difficulty that lies in your path. The public has no particular desire to be educated! It is much more concerned with Willie's tonsils!

But if you want to see our utility civilization evolve along sensible lines, unmarred by dangerous shocks and strains, if you want your own jobs to stand as monuments of personal achievement—you are going to assume this educational responsibility—and find a way to do the job that needs to be done. Perhaps an advertising man, whose livlihood depends upon his ability to "educate" this same public to a desire for goods and services can contribute a few practical suggestions.

First, however, may I again emphasize one thing.

This responsibility of educating the public to a broader appreciation, both of its utility services and the community consciousness of the men who direct them, rests equally upon all of you—whether you represent privately owned companies or public authorities.

I am inclined to believe, in this respect, that the men who work for private corporations have been made somewhat more acutely aware of their public relations responsibilities than those who work for the public direct. Generalities like this are always dangerous—I have read and heard about two publicly owned systems which, by every standard that I know anything about, are doing top-notch jobs in this respect, and you undoubtedly know of others. But there is some reason for believing that, as a broad observation, this one will hold water—that special water used only in discussions like this.

Certainly, the men who work for private water companies have been given a strong incentive to consider these questions. They have seen the threat of eventual dissolution which has been dangled over the heads of the privately owned power companies, and have had presented for their consideration the possibility that at some time a wave of popular feeling might insist that all utilities come under governmental ownership. It is only natural that they should be taking steps to protect their own jobs.

I believe that the special danger confronting the man who already

works for an agency of government, who—to bring the question to your specific case—directs the operation of a municipal waterworks, lies in the existence of a feeling that, since he already works for the people, he neither can nor needs to sell himself or the value of his system to his bosses. His danger is that of seeing himself as a specialist, paid by the citizens to keep a water supply, which they all know they need, pure and plentiful—and no more. As a result, he is apt to lose himself in the details of his work, leaving to the elected officers of the community the whole job of telling its citizens what his and all the other municipal departments under their general stewardship are doing.

But it is well to remember that these elected officials have a special point of view in their appeals and reports to the public. They are primarily interested in justifying their expenditure of the taxpayers' money. A department which is self-supporting—or which is an additional source of city revenues—is not so apt to receive from elected officials the public support, the public encouragement and the general publicity given departments which are primarily revenue consumers. The more efficiently a water department functions, the less likely it is that they will be stimulated to wave flags in its behalf. They, too, are prone to take this utility civilization for granted.

In referring to this general situation I have used the red flag word "danger" advisedly. If we are agreed that the consequences of our utility way of living are as far-reaching as have been described—if we are agreed that public opinion expresses itself as outlined—then we must agree that it is indeed dangerous for a municipal water works executive to feel either that, as a public servant, he *should* do nothing, or that, public apathy being what it is, he *can* do nothing.

Dangerous? Yes, dangerous to your own careers!

I do not consider it my function on this occasion to rattle skeletons or parade black cats across your path. But may I remind you that any dissatisfaction which may arise or which may be cultivated in the public mind is going to focus on you as individuals! We always have in our midst men eager and waiting to leap to the crest of any wave of public sentiment and ride it to their own selfish advantage. They point the stern finger of accusation—they shout "incompetent" and "wasteful" and "unprincipled"—at every man who happens to stand in their path. Once mass feeling has been aroused they find it tragically easy to get the mob to bellow after them "Off with his head!"

In your own enlightened self-interest teach your public all that it

can absorb about its water-works system and the management thereof. It is your right to do so. It is your duty to do so. For you are the only ones who can tell the people of your community the things they ought to know.

Even if you have no advertising or publicity budget, there are plenty of things that you can do.

A modest appropriation would of course come in handy. But I realize that in many communities there is believed to exist a sentiment that public monies should not be used for purposes of this nature. I personally feel that this conviction does not rest on sound reasoning.

Municipal government affects our lives more directly than any other publicly constituted authority. The details of its functioning are therefore of the utmost personal concern to every citizen. Speaking in that capacity, I for one, am convinced that, compared with the total bulk of municipal expenditures, the tiny percentage required to provide us stock-holders with well-organized, pertinent, and above all, interesting information about our civic corporation is a thoroughly justified investment!

Returning, at last, to the question of what to do and how to do it, permit me to state that I hold no patent on the suggestions I am about to make. I am acutely aware of the fact that to an audience like this, much of what I have to say will come as an old refrain. I know that certain of you are doing everything that I can mention—and more. But I also know that sometimes the new bottle can give an old wine a richer color.

As I see it, there are two general aspects to this job of educating the public. The first consists in developing an interest in the water service itself. The second is concerned with building faith in you men who direct that service. Neither can be done quickly—you are going to have to work a long time before results begin to show.

To create an appreciation of what the community's water service consists of, it is first necessary to create in the people's minds a picture of your system and how it functions. And the most effective way to do that is not to tell them about it, but to get them to see with their own eyes as much of your physical plant as can be shown.

How do you do that? Well—have you ever tried inviting them!

I attended a convention recently at which the absence of members' wives was noted. There was quite a discussion about ways and means of persuading the dear ladies to attend. Some very fancy ideas were offered. But the whole discussion came to an abrupt end

when one gentleman finally arose and said "I didn't bring my wife because nowhere in all the pre-convention literature sent me was there a single mention of the fact that wives were invited or would even be welcome!"

Are you letting the public know that it is welcome to visit your pumping stations or filters or aeration plants or laboratories? That's no job—all you have to do is to print a line or two of invitation on the face of the water-bills. And a list of the establishments worth visiting on the back.

I don't say that this will produce mobs of visitors. It is merely a first step. But have you taken it?

And have you taken the second step? Have you seen to it that visitors are treated courteously when they do come around? If citizens are interested enough to want to inspect essential units in their water supply system, they certainly deserve an interested reception from the men on the job.

Make it your business to check this for yourselves. Get some of your personal acquaintances to go around without identifying themselves. Find out how they are treated. If visitors must be turned away, see to it that they are turned away with logical and polite explanations. Train watchmen and guards to answer stock questions with informative answers. Be sure that they know the names of key men to whom more serious inquirers may be referred. If conditions are such that it is not practicable to permit visitors to ramble around at will, establish definite visiting periods and assign specific employees to the duty of showing groups through.

It is the worst kind of foolishness to do anything constructive towards encouraging the public to visit your plants until you are sure that your efforts will be backed up by those of your subordinates with whom it will come in contact.

Once satisfied on this score, you are ready to undertake some more definite plan of action.

Simple invitation is better than silence—but it will find a response only among the most civic minded of the community. To attract wider interest you must break through the public's apathy—you must divert it from its ever-present concern with Willie's tonsils! You must give people something to talk about—something which, by *their* standards—*not* yours—is interesting.

Probably the best example I can offer on this point is that provided by Seattle's famous municipal utility executive—Mr. J. D. Ross.

Mr. Ross realized from the beginning that a vital part of his job was to keep the citizens of Seattle convinced that their municipal electric plant was something to be proud of. And he went about that end of his business with a type of canny showmanship deserving careful study by all of you.

He was particularly anxious to get people to see his magnificent hydro-electric plant, built high in the mountains back of the city, and he deliberately developed around it a stunt show-place sure to attract visitors. In the mild valley below the icy glaciers he created a beautiful forest glade, filled with rare plants and unusual trees. Shifting colored lights played on tumbling cascades, and appealing strains of music fell on the ears of the beholders.

Mr. Ross realized that if you invited people to visit a hydro-electric plant half of them wouldn't know what you were talking about. But a tropical glade next to a glacier—that was something to see—something to "oh" and "ah" over—something to show the people from out of town! He knew that, sub-consciously, they would also absorb a picture of his great feats of hydro-electric engineering—and tie the whole wonder into one proud impression!

I recognize, of course, that few of you have such exciting natural wonders to play with. But a simple reservoir, with its sparkling surface and its bordering trees can be given extra appeal with comparatively little effort. Do a bit of landscape gardening, arrange some parking space, provide a picnic grove below the dam, build a summer house commanding the lake—make it an objective for the folks taking a Sunday afternoon's drive. You must of course protect the water, but that doesn't mean you have to do so complete a job of fencing in that people can't be given an opportunity to enjoy the view from at least a few selected vantage points.

Or take a second example. An aeration plant is a beautiful and dramatic thing to see—the appeal of the fountain is as old as Rome. Give the people comfortable benches from which to watch it—provide promenades and lay out some flower beds around the edges—treat it as a spectacle.

And there is one thing you can do that will give a touch of showmanship to almost any kind of a plant—a laboratory, a pump house, anything—so long as you have a bit of ground suitable for landscaping. Install a lily pond!

To ask a group of engineers to go out planting water-lilies sounds like a bid for a horse-laugh. But I am not talking to you as engineers—I'm talking to you as manipulaters of the mass-mind. To John Q.

Citizen the relation between water and water-lilies is quite natural—water-lilies are something worth making a trip to see, they are beautiful and not apt to be within his normal daily round of experiences. Make a deal with the park department—get all kinds of unusual species—give people something to "oh" and "ah" about. Get them to talking about the Water Department's lily pond—you will find that something like this will cause more people to realize that they have a Water Department than all the reports you could issue in a hundred years!

So much for devices to get the public to see your plants. Now just a word about making their visits mean something educationally. The simplest way to achieve this purpose is to use plenty of well-designed, attractive but not too conspicuous bulletin boards, on which can be placed a few easily-understood, non-technical sentences telling the people just what they are looking at and just what part it plays in providing them with water. Something more than the usual "Green Hills Reservoir—City of Metropolis" is called for.

In providing such information bulletins, watch one thing carefully. Avoid statistics that look like social-security numbers. For example—in the case of a great metropolitan system with a series of huge reservoirs don't merely say that the capacity of one of these impressive lakes is so many million gallons. Bring the message home by some phrase like "You drink this reservoir dry once a month!" Not strictly true, of course, but more apt to convey the truth than the truth itself.

Having busied yourself with the dramatizing of your system, don't depend altogether upon the natural flow of public interest. Stimulate it. Invite the attention of your local newspapers to what you are doing. Play ball with the reporters and photographers. Many things about your water service may prove of greater interest to them than you have realized.

Undoubtedly all of you saw the spread of color pictures in a recent issue of the Saturday Evening Post, showing views of the new Los Angeles aqueduct in its march to the sea. I do not know who inspired the taking and the publication of these photographs—but one thing I am sure of. They represent a high degree of intelligent cooperation between the water supply authority and those actually responsible for the appearance of the material.

This is a brilliant example of the sort of publicity that creates civic pride and starts people to talking.

There is another vehicle for public education which is so obvious

that I have hesitated even to mention it. That, of course, is your public school system. Cooperation with the schools is so simple, so appropriate and so valuable that I cannot imagine any of you failing to utilize this natural civic relationship to the utmost degree. Of all the devices that you can employ, none will have more lasting effects. If you, by any chance, are not now getting every school child into your plants at least once in his school life, make this your first order of business!

Only one further piece of advice might be offered in this connection. Make sure that the men who actually show the youngsters around are trained to keep their explanations simple and interesting and easily understood.

And now—let us look at the other side of the job of educating the public. This calls for a somewhat different type of activity on your part, and has as its objective the creation of public faith in your personal understanding of the community and your personal interest in its problems.

The spirit back of your efforts along these lines must be the same in all cases—but the technique will vary with the size of the community. In places ranging up to—say 25,000 in population, the degree of influence which you come to possess will depend largely upon your direct personal relations with your fellow-townsmen. The way you speak to people on the street, the attention you give the preacher on Sunday, the kind of salad your wife serves the Ladies' Bridge, Sewing and Culture Club—these all play their part in establishing your reputation in the community. In smaller places you must—in a very literal sense—be the "good neighbor." For a more detailed idea of what I mean read Mr. John Gough's heart-warming report on the "One Man Town" in the April issue of your Association's Journal.

As places grow larger, the purely personal note becomes less important—fewer and fewer people know or care whether you eat peas with a knife or dine on caviar—until, when we get to cities over a couple of hundred thousand, an entirely different technique is called for. To gain and keep public interest in metropolitan communities you must deliberately seek the spotlight and make the most of those moments when it shines upon you. You must say and do things that will cut through the public's absorbing interest in its own affairs.

But though the technique may vary, there is no hamlet so small nor any city so large that a good job cannot be done. The important

thing to remember about the big city is this—that once you have acquired a personality in the eyes of the public, the complete machinery by which a great urban society keeps informed is at your command. Mr. Robert Moses of the New York Park Department heads an agency of municipal government no more important than a half a dozen others. Yet because he has developed a vital philosophy, and because he expresses his views vividly and with dramatic action, he is constantly being interviewed and photographed and "written up." As a result, most New Yorkers are convinced that today they have a great park system and a great park administration.

There are three steps in the creation of a positive public sentiment on your own behalf. First, you must study the community and its people. Second, you must evolve a philosophy relating your field of work to the future progress of the community. Third, you must tell people about it!

The very life of your city depends upon the service you direct. Isn't it, then, of considerable importance to you to know just what kind of life would be destroyed if that service ever failed?

You must make it your business to see your community as something more than a network of mains and outlets—you must make it your business to see it as a living organism.

Do you know what your fellow townsmen are really like? Do you know how they make their living? Do you know what they are thinking? Do you know the history of the town? Do you understand the social, the economic, the geographical factors that have shaped its destiny?

Go back from here and look at your communities as though you had never seen them before. Take some time out from your regular duties and go out talking to people—to merchants, to manufacturers, to workmen, to old ladies at soda fountains. Ride the street cars and buses, read the local histories in the library, go up in a plane and look at the place from the air. Try to establish in your own minds an independent picture of your town or city.

When you have acquired such a picture, sit yourselves down to some good sound thinking. Here's the town! What about it? Where is it heading? What does its future hold? What are the discouraging aspects of the scene? What are the encouraging ones? What *should* be done? What *can* be done' And how?

You have more than a right to seek answers to these questions. You have a vital concern in the answers eventually arrived at. For—

—and this is no paradox—the life blood of an urban community is water! You represent the human force that keeps the heart pumping and the veins healthy!

Set for yourselves, then, the problem of finding answers which in your own independent judgment seem wise and true. Find answers which can form your personal contribution to the social philosophy of your fellow citizens. Formulate them into a code of civic objectives—and then, tell your story loudly enough so that all may hear.

There is only one way to make a strong personal impression on the public—and that is to get out in front of the public and let it see you and hear you. Fortunately, as a public officer, you already occupy a position sufficiently conspicuous to attract attention easily. The crowd won't bother to look up at you as long as you remain silent, but when you do speak, they won't have a lot of trouble finding where the words are coming from. You don't have to do a lot of ground-work building a rostrum—all you have to do is to take full advantage of the platform you already have.

Get out and do things—get out and talk. Be there when the neighborhood civic association celebrates the completion of a new water-main. Accept that invitation to address the United Parent Teachers Association. Join the boys of the Real-Estate Board at lunch.

There is hardly a club or association in the community which can't be interested in some phase of your activities. Show the business men how their favorable fire insurance rates depend upon the proved performance of your water service. Point out to the civic boosters how their campaign for more industries must rest upon your ability to keep pace with adequate water supplies. Describe to the mothers how the health of their families hangs on the purity of each crystal drop that slips from the faucet. Talk to your public in terms of its varying interests. Then, having shown your concern with the things that concern your hearers, give them something of this philosophy you have developed concerning the community as a whole.

The advantage of such a planned program is that you don't have to confine your public appearances to the mere reporting of what your waterworks is and what it does. Every listener likes to feel that he has received a message from a speaker. He may do nothing about it—but he is impressed nevertheless. Make it your business to combine sound water-works information, an appeal to your hearers'

selfish interests and a vision of general community progress into a whole which will be clearly identified as a message!

Once you have started such a campaign, you will find that the ball will keep on rolling. People will hear about you, they will listen to you, they will talk about you. They will come to think of you as one man who is interested in their Willies' tonsils instead of his Willie's tonsils.

And that is the best possible position in which any utility executive—public or private—can find himself!

PREVENTION OF CORROSION BY THE APPLICATION OF INHIBITORS

By F. H. Waring

Chief Engineer, Ohio Department of Health

The treatment of public water supplies to prevent corrosion offers a most interesting and difficult problem. The subject seems to divide itself naturally into two parts—the handling of waters which are naturally corrosive and the handling of waters which become corrosive after water purification or water softening. It is not the intent of this article to go into the research aspects of the subject, but to portray to the water works operators some of the problems that are of interest to them, especially where treatment of the public water supply is practiced. Consideration will therefore be given to the second phase of the problem almost entirely, namely, the handling of corrosion which is the result of water purification or water softening treatment.

Corrosive action of water can be a complex subject for the average water works man to understand, especially when attempt is made to delve into the chemistry involved. The water works man, however, is not at a loss to understand the effects of corrosive action of water upon piping. He is all too familiar with the complaint of the householder of red water troubles that occur in service lines and dead ends of distribution systems where the water is corrosive. From first-hand knowledge of effects of corrosion he naturally turns to remedies in the way of treatment. At the same time, if the water works operator can be furnished a yardstick whereby the water may be measured in advance of entering the distribution system and found to be either corrosive or non-corrosive, he is better able to take the steps toward the remedy.

A paper presented before the meeting of the Kentucky-Tennessee Section at Louisville, March, 1938. The author, F. H. Waring, is Chief Engineer of the Ohio State Department of Health, Columbus, Ohio.

One of the simplest tests that has been devised to indicate to water works men whether water is corrosive or not is the marble test (1), developed some twelve years ago, which essentially is as follows: The water in question is tested for total alkalinity, then to the water is added a small amount of powdered calcium carbonate. After shaking the mixture for several minutes, a filtered portion is tested again for total alkalinity. If the sample is found to have increased in alkalinity, the water is deemed to have been corrosive. More recently this simple test has been elaborated upon somewhat by the substitution of the measurement of pH in place of the measurement of alkalinity. The pick-up noted in pH has been termed the "corrosion index" of the water. Credit for this special application of Tillman's original test as modified by Baylis is given to Professor Langelier (2) of the University of California.

TESTS FOR WATER CORROSION

It might interest the water works operators to know that this corrosion index test is now a regular part of the water testing routine as conducted by the Ohio Department of Health laboratories on all samples of water submitted. We are especially interested, of course, in the public water supplies and are watching with interest the corrosion index that may be indicated for treated waters. In addition to our own laboratory making this test, we are urging all of our men in charge of water treatment plants to include this test as a routine. It is apparent that a comparison of the corrosion index figures with known conditions upon the distributing system will tell us what index figures to attribute to a corrosive water that is likely to give us trouble. From the limited tests that have thus far been made in our laboratories, we are inclined to believe that a pick-up in pH of 0.2 or less, even in cold water, indicates that the water should be given treatment to overcome its corrosive quality. This amount is somewhat less than the limit of 0.5 noted by DeMartini (3) for five California municipal water supplies.

THE RÔLE OF LIME IN CORROSION PREVENTION

Leaving aside the technical questions of what constitutes a corrosive water, let us proceed at once to take up from the water works operator's standpoint the question of what may be done to correct the corrosiveness of water. Considering just the waters that are being purified or softened, it is to be noted that several treatments have been practiced during the past fifteen or twenty years to over-

come the corrosive quality of water. For example, it has long been known that in water softening without subsequent recarbonation the water treated with lime and soda was left with a tendency toward deposition, or just the opposite of a corrosive water. This was due to excess of calcium carbonate in solution or in colloidal form which deposited upon the pipe surfaces slowly, thus forming a protective coating upon the piping. With the advent of excess causticity in lime softening practice, with its attendant treatment with carbon dioxide (or recarbonation as it is called), a swing toward slightly corrosive conditions was experienced, perhaps due at first to too much recarbonation. It was also noted in water purification practice where lime was used together with iron sulphate as a coagulant, that the treated water contained an appreciable amount of the protective coating of calcium carbonate. Therefore, where coagulant alone was being used, some of the water treatment plant operators deliberately applied lime to the filtered water in order to obtain the protective coating benefits of the lime (4).

SUBSTITUTION OF SODA-ASH AND CAUSTIC SODA IN PLACE OF LIME

The addition of lime to the clear well had some attendant difficulties and disagreeable features. Accordingly, a few water works men substituted soda-ash, relying upon the principle of increasing the alkalinity to render the water non-corrosive, instead of the principle of adding an ingredient that furnishes a protective coating. Both soda-ash and caustic soda have thus been used to increase the alkalinity after water treatment.

USE OF SODIUM SILICATE

More recently sodium silicate has been used in corrosion prevention. We have in Ohio several small municipal water softening plants of the zeolite type which treat ground water for the removal of iron and for softening. It is the usual practice in these instances to remove the iron by aeration and sand filtration. Ordinarily three-fourths to four-fifths of the iron-free water is then passed through zeolite, subsequently to be mixed with the one-fourth to one-fifth portion of the hard but iron-free water. The resultant product is not water of zero hardness but water of probably 50 to 80 parts per million hardness. In practice it has been noted that a number of the ground waters so treated have been corrosive. Accordingly, several of these plants have been using sodium silicate, applying the same to

the softened water. The use of sodium silicate does increase the alkalinity somewhat, but the principle involved here for corrosion prevention is the formation of a protective coating of the silicate on the piping.

More recently there have been advocates of the use of sodium silicate in conjunction with coagulant in water treatment practice. These advocates claim economy of coagulation as well as a betterment of the floc. This seems to be borne out with certain waters. Just how much of the silicate thus added remains in the filtered water for the protective coating is somewhat of a question, although it may be that using sodium silicate in this manner accomplishes the dual purpose of bettering coagulation and producing a non-corrosive filtered water.

AMOUNTS OF CHEMICALS APPLIED TO PREVENT CORROSION

The question naturally arises as to how much of these various ingredients it has been customary to apply in order to render the purified or softened water non-corrosive. Since the "Marble" test was developed, most of the operators have used this means of measurement to determine if the quantity added was sufficient. The actual amounts have varied from a few tenths of a grain to two grains per gallon. At one time the Mahoning Valley lime-soda water softening plant serving Youngstown, Ohio, added between 2 and 3 grains per gallon of soda-ash to the filtered water in order to increase the alkalinity and thus prevent corrosive water. At the present time, however, this plant has abandoned the application of soda-ash to the filtered water and has dropped back in the softening schedule; that is, the water is not softened to as great a degree as formerly and the alkalinity is not reduced to such a low figure as formerly.

It is of interest to point out to the men who are operating water softening plants using the lime-soda treatment, that care must be exercised not to reduce the alkalinity by such treatment to too low a figure. For example, a few years ago we were of the opinion that a water must not be lowered in its alkalinity below 30 parts per million. During the past year we have reason to believe that this figure is more nearly correct at 40 parts per million. It should be understood that this alkalinity refers to calcium carbonate and calcium bicarbonate alkalinity. It is also apparent to us from experience in lime-soda softening that the range between a corrosive water and a depositing water is very narrow. It is better, therefore, to conduct the treat-

TABLE 1

Silica content of Ohio public water supplies, untreated
(January to March, 1938)

MUNICIPALITY	SOURCE OF SUPPLY	SILICA (P.P.M. SiO_2)	
Adena	Wells	10, 12, 14	
Bloomville	"	18	
Cadiz	"	12	
Circleville	"	20	
Coldwater	"	12	
Dayton	"	10	
East Palestine	"	17	
Edon	"	22	
Englewood	"	10	
Holgate	"	10	
Montpelier	"	22	
Ottawa	"	9	
Reynoldsburg	"	14	
Sylvania	"	13	
Van Wert	"	12	
West Unity	"	16	
		Avg. 14	
Canton	Wells	12	*
Norwood	"	18	*
Springfield	"	12	*
Zanesville	"	12	*

* (Data from U. S. G. S. Water Supply Paper #658, 1934.)

TABLE 2

Silica content of Ohio public water supplies, lime-soda softened
(January to March, 1938)

MUNICIPALITY	SOURCE OF SUPPLY	SILICA (P.P.M. SiO_2)		
		Raw	Softened	
Alger	Wells	12	7	
Bloomdale	"	10	6	
Hebron	"	14	12	
Johnstown	"	14	7	
Leesburg	"	14	10	
Mt. Sterling	"	13	6	
Mt. Victory	"	16	8	
		Avg. 13	Avg. 8	
Marion	Wells	16	6	†
Massillon	"	15	8	†
Newark	Licking River		4*	†
Sandusky	Sandusky Bay	10	6	†
Water purification, not softening				
Barberton	Wolf Creek		2.1	†
Cincinnati	Ohio River		3.1*	†
Elyria	Lake Erie		3.0	†
Toledo	Maumee River		2.4	†
Youngstown	Meander Creek		3.5	†

* Annual averages from composite samples.
† (Data from U. S. G. S. Water Supply Paper #658, 1934.)

ment on the side of the depositing characteristic rather than the corrosive side. If this viewpoint is taken in the treatment, of course incrustation of the sand grains will result, but we feel it is better to renew sand occasionally than it is to have the expensive undertaking of renewal of service piping.

PROBLEMS IN SILICATE TREATMENT

Coming to the question of sodium silicate treatment, it would seem quite logical to bring about an increase of silica content of the supply, provided that the water so increased in its silica content is

TABLE 3

Silica content and corrosion index of Ohio public water supplies using zeolite softening, without any accompanying anti-corrosion treatment

(January to March, 1938)

MUNICIPALITY	SOURCE OF SUPPLY	SILICA (SiO_2)			CORROSION INDEX		
		Raw	Softened	Tap	Raw	Softened	Tap
		p.p.m.	*p.p.m.*	*p.p.m.*			
Berea	River	7	7	7	1.1	1.2	1.0
Cedarville	Wells						
Cuyahoga Falls	"						
Genoa	"	10	11	12	0.5	0.2	0.1
Grove City	"	12	13		0.3	0.7	
Lowellville	"						
Mechanicsburg	"	12	12	12	0.4	0.4	0.7
Wapakoneta	"	14	12	12	0.5	0.5	0.4
Worthington	"						

comparable with natural waters not so treated. To this end our laboratories have made a study since the first of January to determine the natural silica content of the water supplies of Ohio. We have observed that surface waters, generally speaking, carry from 2 to 7 parts per million soluble silica (SiO_2). On the other hand, some of the ground waters used for public water supply contain from 25 to 30 parts per million. The average for the ground waters seems to be from 10 to 15 parts per million. One well water analyzed by the city of Dayton and serving a private establishment was found to contain 110 parts per million of silica. From the foregoing figures it will be seen that the addition of, say, 8 parts per million SiO_2

TABLE 4

Silica content and corrosion index of Ohio public water supplies using zeolite softening followed by anti-corrosion treatment

(January to March, 1938)

MUNICIPALITY	SOURCE OF SUPPLY	ANTI-CORROSION TREATMENT		SILICA (P.P.M. SiO_2)			CORROSION INDEX		
		Chemicals used	p.p.m. applied	Raw	Treated	Tap	Raw	Treated	Tap
Burton	Wells	Sodium silicate	?	13	18	16	1.0	0.6	0.9
Edgerton	"	?	(Under constr.)						
Elmore	"	Caustic soda Sodium silicate	8.3 5.6	13	13	12	0.3	0.3	0.2
Lancaster	"	Soda ash	15.4						
New Bremen	"	Soda ash Sodium silicate	8.0 4.0	14	14	14	0.3	0.2	0.2
New London	"	Caustic soda Sodium silicate	5.8 5.8	13	13	13	0.2	0.3	0.0
New Madison	"	?	?						
New Philadelphia	"	Soda ash	33.5						
North Baltimore	"	Soda ash Sodium silicate	12.0 12.0	13	14	13	0.5	0.0	0.1
Pemberville	"	?	?						
Plymouth	"	Caustic soda Sodium silicate	18.0 6.0	14	15	16	0.4	0.3	0.2
Rittman	"	Caustic soda Sodium silicate	8.1 4.6	13	14	13	0.3	0.1	0.1

Totals:

Soda ash, only	2
Soda ash and sodium silicate	2
Caustic soda and sodium silicate	4
Sodium silicate, only	1
Unknown	3
	12

Zeolite softening plants using anti-corrosion treatment—12 as of March 22, 1938.

Zeolite softening plants not using any anti-corrosion treatment—9 as of March 22, 1938.

Total municipal zeolite softening plants—21.

may not be significant. Appended to this paper will be found a tabulation of the silica content of several Ohio public water supplies; also the increase shown by the few municipal supplies where actual treatment with sodium silicate is practiced. Briefly, the silica content is increased in the treated water only an insignificant amount.

TABLE 5

Silica content of public water supplies outside Ohio

(Significant for high SiO_2)

STATE	MUNICIPALITY	SILICA (SiO_2)	SOURCE OF SUPPLY
		p.p.m.	
Arkansas	Texarkana	39	Wells
California	Fresno	80	"
	Pasadena	33	"
	Stockton	57	"
Delaware	Dover	49	"
	Milford	54	"
Florida	St. Augustine	28	"
Georgia	Brunswick	37	"
	LaGrange	43	"
	Savannah	56	"
Idaho	Boise	32	"
	Twin Falls	32	Surface, filtered
Indiana	Lafayette	24	Wells
Kansas	Kansas City	41	"
Louisiana	Alexandria	52	"
	Lafayette	40	"
Mississippi	Clarksdale	78	"
	Lourel	50	"
	Natchez	51	"
Nevada	Elko	80	"
Washington	Longview	56	"

Above from U. S. Geological Survey Water Supply Paper 658, 1934.

Based upon our limited experience, it would appear that the use of sodium silicate in nominal amounts for treatment of our public water supplies may be safely permitted.

QUESTIONS OF PUBLIC POLICY INVOLVED

Consideration of the suitability of sodium silicate for water treatment practice brings up questions in physiology as well as psychology. Those engaged in the water works business have to

proceed with caution in adopting new ideas in water treatment until it is demonstrated by exhaustive research or experience that a departure in chemical treatment will not cause harmful effects physiologically. The chemist thinks of sodium silicate as just another chemical that may be used in water treatment practice; but, if you tell the public that the man in charge of the water purification plant is adding "water-glass" to the supply, he should be prepared to have plenty of criticism directed his way. Along this same line, we recently found that the reduction obtained in fluoride content by lime softening depended upon the magnesium content of the raw water. In order to increase the magnesium in the raw water, it was suggested that magnesium sulphate be added. From the chemist's standpoint this practice might be entirely satisfactory, but from the public viewpoint the addition of Epsom salts to the raw water would never do. It is thus apparent that the water works man must proceed cautiously in adopting innovations in the chemical treatment of water. *By no means should he make use of secret compounds, the exact composition of which is not definitely known, in the treatment of public water supplies.*

PROPOSED USE OF SODIUM CHROMATE AS AN INHIBITOR

More recently there has been proposed for public water supply treatment a corrosion inhibitor which for the most part is sodium silicate, but which also contains an appreciable quantity of sodium chromate. The material is marketed as a proprietary product by an Ohio firm. Upon analysis the material shows the following characteristics:

Specific gravity	1.41	
Total solids	65.6	grams per 100 c.c.
Silica, SiO_2	20.00%	by weight
Chromium, terms of sodium chromate, Na_2CrO_4	0.44%	by weight

If the directions of the company were followed in the application of the inhibitor, the water would be treated with 0.31 parts per million sodium chromate (Na_2CrO_4), corresponding to 0.1 part per million chromium (Cr). Last summer one of our county health commissioners requested an opinion as to the safety and advisability of permitting the use of this material in the public water supply system of a centralized school. A search of the literature revealed a scarcity of information as to the physiological effects, if any, of the presence

in drinking water of this amount of chromium. Considerable information was revealed showing that some salts of chromium were toxic. This was especially pointed out in the literature dealing with the use of chromium compounds in the plating industry. Air, laden with dust impregnated with chromium, which resulted from the polishing of the metal products, was found to have caused toxic effects upon the workers. It is also known that the compound of chromium, or the chromate, known to the chemist as hexavalent chromium, has toxic properties.

The entire question of incorporating chromium in an inhibitor for public water supply treatment was therefore felt by us to be one for exhaustive research before we could say that such a procedure as recommended by the proprietary company was safe. The Director of Health requested an opinion upon this subject from the Surgeon General of the U. S. Public Health Service. Likewise, inquiry was directed to the officials of the American Water Works Association and those of the American Medical Association. The results of these inquiries serve to corroborate the opinion expressed by our own technicians, namely, that sufficient evidence was not at hand to indicate the physiological effects of any amount of chromium in drinking water. Views have also been expressed by Dr. Sidney Negus (5), and others seeming to point to the same conclusions; namely, in the absence of definite information great caution must be exercised in the use of chromium in treatment of drinking water. Almost everyone agrees that an exhaustive research must be conducted before we will be able to say that chromium in any amount may be safely used. In a recent letter the Director of Health of Ohio has requested the Surgeon General of the U. S. Public Health Service to cause to be undertaken such a research as will demonstrate the answer to the question concerning chromium.

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TESTING OF SOILS PRIOR TO INSTALLATION OF METAL PIPES

By Robert R. Ashline

When Secretary of Commerce, Herbert Hoover said: "It is only through the elimination of waste and the increase in our national efficiency that we can hope to lower the cost of living, on the one hand, and raise our standards of living, on the other. The elimination of waste is a total asset. It has no liabilities." Corrosion research is aimed at elimination of the three billion dollars waste annually sacrificed to corrosion of metals.

THE ECONOMIC SIDE OF THE PICTURE

It has been estimated by competent authorities that of the 1,200,000,000 long tons of rolled iron and steel products in use in the world in 1931, two per cent per year is lost by corrosion. Although it is true that some of this wastage is recovered as scrap iron, no account is taken in the figure quoted of the high cost of salvaging such items as underground pipe lines whose serviceable life has ended and therefore must be renewed. The economic loss occasioned by leakage of the commodities conveyed by these pipe lines, and the cost of damages to other property involved when, for instance, a major water carrier releases a seepage flood that weakens the foundations and undermines buildings, sometimes involving loss of life as well as property, is not even considered in this estimate.

The petroleum industry has found it necessary to add a rust charge of one cent a gallon to the price of gasoline. An appraisal of the "rust charge" included in the consumer's water bill may be had from a study of figure 1, which includes a graphic account of the soil corrosion problem experienced by the water distribution system of the City of Los Angeles. Figure 1 does not show anything of the excessive cost of excavation and trenching incident to replacement of no-longer-serviceable pipe lines, nor the cost of making multitudinous repairs necessary to keep the pipe in serviceable condition while in

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use. These last two items combined are far in excess of the cost of metal used, and would be almost wholly eliminated if corrosion could be prevented.

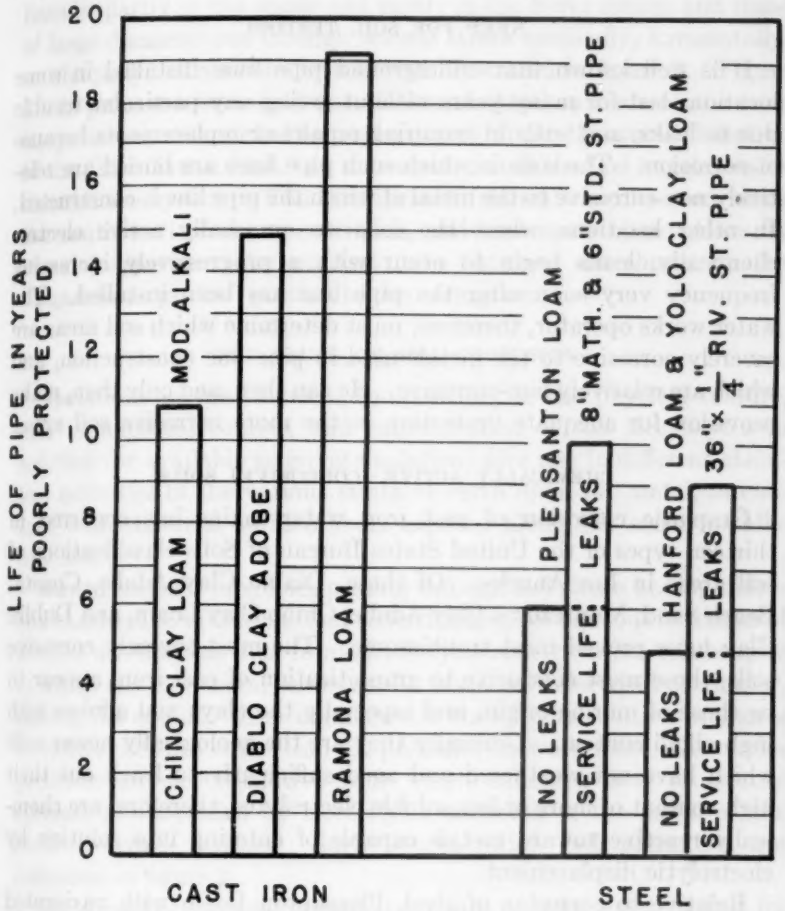

FIGURE 1

DIMINISHING SUPPLY OF IRON ORE VS. COST AND CONSERVATION

The available iron ore supply of the United States is rapidly diminishing, consequently the cost of iron and steel products is expected to go up with spectacular advances as the supply approaches the vanishing point. It is therefore imperative that not only iron products which have outgrown their usefulness be salvaged and their scrap value applied toward the cost of new construction, but also

that every conceivable effort be made to conserve a very large proportion of that two per cent annually rusted away and therefore irrevocably lost to industry.

NEED FOR SOIL TESTING

It is well known that underground pipe lines installed in some locations last for many years without giving any particular trouble due to leaks, and without requiring repairs or replacements because of corrosion. The soils in which such pipe lines are buried are relatively non-corrosive to the metal of which the pipe line is constructed. In other locations, where the soils are unusually active electrochemically, leaks begin to occur with a progressively increasing frequency very soon after the pipe line has been installed. The water works operator, therefore, must determine which soil areas are severely corrosive to the metals used in pipe line construction, and which are relatively non-corrosive. He can then, and only then, make provision for adequate protection in the more corrosive soil areas.

CHEMICALLY ACTIVE (CORROSIVE) SOILS

Graphitic corrosion of cast iron water mains has occurred in thirteen types of the United States Bureau of Soils classifications of soil areas in Los Angeles. Of these, Diablo Clay Adobe, Coastal Beach Sand, Montezuma Clay Adobe, Chino Clay Loam, and Dublin Clay have proved most troublesome. The most severely corrosive soils, those most conducive to graphitization of cast iron, appear to be those of marine origin, and especially the clays and adobes with high alkali content. Generally they are the geologically newer soils which have not weathered and aged sufficiently to leach out their high content of more or less soluble electrolytes, therefore, are chemically reactive toward metals capable of entering into solution by electrolytic displacement.

Relative to corrosion of steel, Pleasanton Loam with variegated stratification has caused more galvanic or concentration cell electrolysis of steel water mains per mile of pipe installed than any other soil type in Los Angeles. Life of pipe (poorly protected) in the Pacific Palisades area has ranged from six to ten years. Ten years has been the maximum. Yolo Loam has a bad record, and Decomposed Granite is very corrosive to steel pipe buried in it. Particularly noticeable is the distinct stratification of earth through which the pipe lines extend in these severely corrosive soils. The layers of earth, as observed along the walls of the pipe trench, range from

less than one inch in thickness to several inches or several feet; and from lens-like inclusions of very fine earthy matter to thin or thick layers of shale, sand, lime, clay, etc. In many instances the pipe lines lie partly in the upper and partly in the lower strata, and those of large diameter cut through several strata vertically, horizontally, or obliquely. This condition is well illustrated in figure 2. Figure 2 was prepared from field notations and sketches made at the time a pipe trench was opened for replacement of a badly corroded section of the "Pico Trunk Line," an important unit in the Los Angeles water distribution system. The stratification shown was observed along the south wall of the open trench, and represents observations by visual inspection. Various test data obtained are shown on the "logarithmic profile" portion of the cartogram.

THE CAUSE OF SOIL CORROSION

Variations in the chemical composition, in the physical texture, and in moisture content and concentration of soil electrolytes in solution (or available to go into solution) give rise to different chemical activities of the various strata of earth upon the metal, in contact with different surface areas exposed along the same metallic pipe line.

Buried metallic pipe lines passing through soil strata having different chemical compositions and concentrations of aqueous solutions of ionized electrolytes thus form electrolytic concentration cell couples in which the pipe metal serves as the "external" electrical conductor, closing the circuit. Any unbalance in the *effective* solution pressures (solution pressure minus osmotic pressure) between these cell couples produces an electro-motive-force which causes a flow of electric current, accompanied by electrolytic corrosion of the metal at the anodic contact surface. Such concentration cell potentials are indicated in figure 2.

The quantity of metal corroded per unit of time is determined by the magnitude of the inter-strata electrical potentials generated by electro-chemical action, and is limited by the total resistance of the circuit. Earth resistivity is the largest component of the circuit resistance, therefore, it is one of the most important factors limiting or retarding soil corrosion.

FIELD METHODS FOR TESTING SOIL CORROSIVITY

One of the early methods for field testing of soil corrosivity is illustrated in figure 2. To measure interstratal electrolytic potentials,

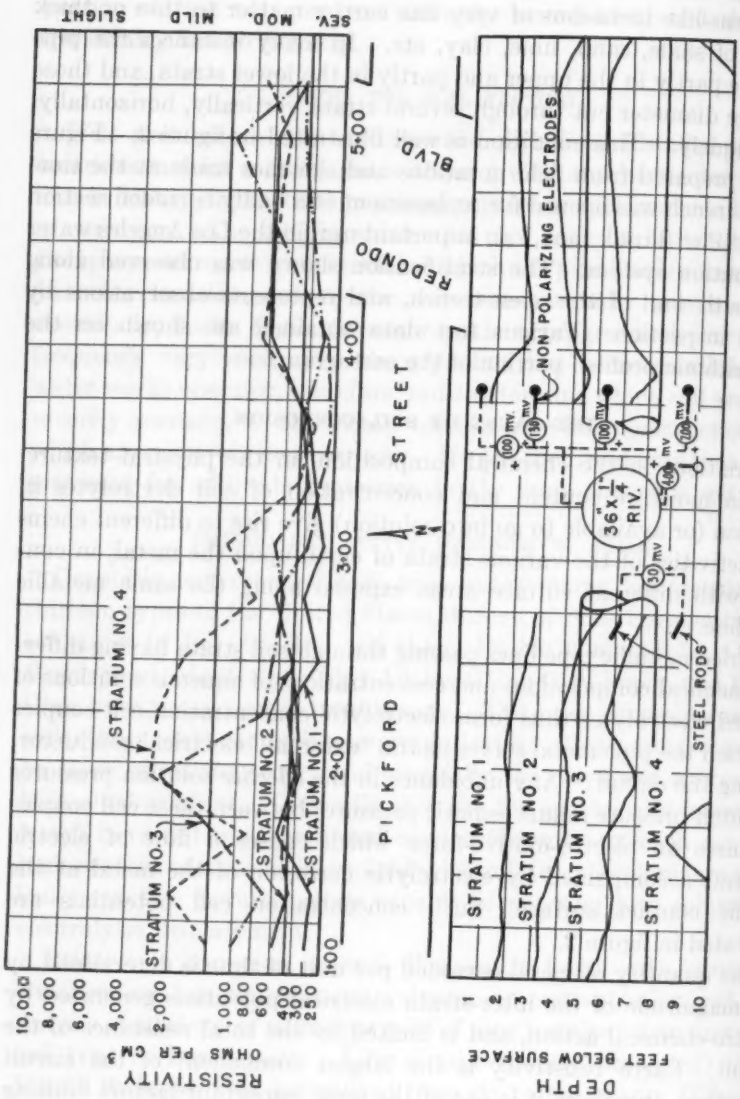

FIGURE 2

CARTOGRAM OF SOIL CORROSIVITY SURVEY AT PICKFORD ST. AND REDONDO BLVD.

the very sensitive galvanometer of the McCollum Earth Current Meter is used for accuracy, and a special 1000 ohm per volt millivoltmeter is then connected in the circuit to obtain the 24-hour record. It has been observed that changes in temperature and moisture during the 24-hour day, especially in locations where lawn sprinkling is a regular daily occurrence, cause variations in the concentration cell potentials. The 24-hour check test, although not as sensitive nor accurate as the galvanometer indication, is of considerable value and importance.

Another method, making use of the same principles of electrochemistry, is used for measuring the quantity or rate of corrosion per unit area of exposed metallic pipe surface. A bright steel rod, having a definite and known surface area of exposure to contact with moist earth, is driven into the ground a few feet away from the pipe. A recording milliammeter is connected between the pipe and the test rod. By measuring the current discharge from, or collection upon, the test rod the quantity of current flow per unit area per unit of time is determined. By application of Faraday's Law of Electro-chemical Equivalents, the quantity and rate of corrosion per unit of surface area of pipe can be calculated from the record of electrical data collected.

Hydrogen ion concentration is regarded by many research workers as an important criterion of the corrosivity of soils. Extensive researches along this line have been carried on by I. A. Dennison of the United States Bureau of Standards, and by P. J. Richards of the Richards Laboratories in Denver. Hydrogen ion concentration can be regarded as a measure of the intensity of tendency to cause corrosive attack by soils upon structural metals buried in them. Total acidity and alkalinity can be regarded as the reservoir of water soluble electrolytes available to maintain the hydrogen ion concentration, until exhausted by leaching or by being used up in chemical combinations. We believe measurements of pH values, and of total acidity or alkalinity, have value in conjunction with other test data as indicators of soil corrosivity. They are measurements of factors tending to cause soil corrosion of underground metallic structures, and should be so regarded.

Several years ago studies were made of the possibility of measuring pH values of soils in place with a portable equipment. The tests, however, seemed too elaborate and precise for general application. The cost of obtaining such data seemed out of proportion to the value and importance of the data which could be collected.

EARTH RESISTIVITY MOST PRACTICABLE OF FIELD TESTS

From the series of tests described above it was obvious that two primary factors entered into the cause and effect of conditions producing electrolytic corrosion of buried metallic pipe lines. First, the inter-potentials between soil strata, or contact concentrations of soluble electrolytes causing unbalances of solution pressures between electrolytic concentration cell couples, supplied the driving force to dissolve and corrode pipe metal. Second, the predominating factor which limited the rate of corrosion possible was the series combination of resistances in the complete electrical circuit. These included earth resistivity; the degree of reverse potentials developed by concentration of solutions of electrolyte at the contact surfaces; the resistivity of polarization and/or oxide films formed at the contact surfaces between metal and solutions; and the electrical resistance of the metallic part of the circuit. Of these, earth resistivity ordinarily constituted the major component.

Earth resistivity is the most easily and economically measured of the measureable factors contributing to or retarding soil corrosion of underground metallic structures. It is most easily measured with the Shepard Earth Resistivity Meter, and with reasonable care exercised by competent field testers, the data collected are sufficiently reliable to give good soil corrosivity indices for the usually alkaline soils of Los Angeles and vicinity. We believe earth resistivity measurements are among the most reliable of all the numerous kinds of tests tried by the Bureau of Water Works and Supply for determining soil corrosivity in our local soil areas. The Shepard Earth Resistivity Meter was therefore regarded as one of the most important contributions to practical field testing of which we know. It measures the major component of the limiting factor regarding soil corrosion.

The earth resistivity data shown on the "logarithmic profile" portion of figure 2 were obtained by measuring the unit resistivities per centimeter cube of the various strata located from top to bottom of the pipe trench with a pair of Shepard Rods. Where the pipe trench has not yet been opened, as in the case of a preliminary corrosion survey, earth resistivity is measured along the route of survey at one, three, and five foot depths. Samples of soil are collected at these depths at the same time, and are brought into the laboratory for further testing.

Figure 2 furnishes a graphic illustration of the contiguity and merging of soil strata through which a pipe line extends. Correla-

tions between the various data which are obtained by both field and laboratory testing of soils is shown on the "logarithmic profile" portion of the cartogram. The most severe soil corrosivity index given by these several tests is considered to be the degree of severity of soil corrosivity against which protection should be applied. Recommendations for adequate pipe protection in the different soils are made accordingly, and the extent and boundaries of the relatively corrosive soils are clearly indicated on the cartogram, along the route of survey.

LABORATORY METHODS FOR TESTING SOIL CORROSIVITY

The first laboratory tests on the corrosivity of soils consisted of chemical and physical analyses of the soils, and of analyses of the corrosion products formed by chemical reaction of soils upon metals buried in them. Measurements of hydrogen ion concentration, and of total acidity and alkalinity, were regarded as particularly important. Analyses of the corrosion products indicated which electrolytes in solution entered into corrosive chemical reactions. Physical analyses and classifications of soils gave information about the intimacy of contact maintained between corrosive solutions with the metal. These tests involved expense greater than results seemed to justify, especially since other less expensive and more practicable tests gave sufficiently reliable information to establish soil corrosivity indices for mapping the various soil areas.

The most generally used and most convenient laboratory test for soil corrosivity in the Los Angeles area is the Corfield-Williamson nipple and can test. This test is easily and economically made, and automatically takes into account the varying tendencies of several factors contributing to soil corrosivity in the final composite result indicated. Electrical conductivity of solutions of soil electrolytes, and the tendency of these solutions to dissolve and corrode anodic pipe metal is measured by this test. A complete description of the Corfield-Williamson nipple and can test was published in the March, 1930 issue of "Western Gas." Correlations of the soil corrosivity indices given by the nipple and can test with actual corrosion experience have usually been consistent and dependable.

A few of the soils tested by the Corfield-Williamson method, soils having an unusual physical structure and chemical composition, did not give good correlations with actual corrosion experience, consequently an attempt was made to determine the reasons for these isolated discrepancies. It was found that those soils which did

not give good correlations with actual corrosion experience and other test data available built up a zone of high resistance at the contact surface between the anodic test nipple and the surrounding sample of moist earth; and that another zone of high resistance was developed at the contact surface between the cathodic can and the sample of moist earth it contained. The high electrical resistance at the anodic surface is attributed to the formation of a film or scale of corrosion products closely adherent to the surface of the anodic metal. The scale of corrosion products formed on the surface of the test nipple has been observed under a microscope for relative continuity and other characteristics. The high resistance at the contact between the soil sample and the can is attributed to the formation of a polarizing film of hydrogen at the cathodic surface, under the condition of applied direct current potential characteristic of this test, followed by shrinkage and drying out of the soil sample during the 24-hour period of the test.

Features of the Putnam Unit Cube Method (described in A. P. I. Proceedings, Vol. 2, Sec. IV, 1930, p. 122 and also Vol. 16, Sec. IV, 1935, p. 66) were studied with the hope of overcoming the poor contact, and consequent zone of high resistance at the cathodic surface, by means of a pressure piston to maintain firm contact between soil and metal. A well designed pressure piston would also prevent much of the evaporation of moisture during the test, since the surface of exposure to the atmosphere would be covered by the piston. This condition would more nearly represent the degree of exposure and aeration of underground pipe lines. Insufficient work has been done to date on this variation of the nipple and can test, however, to permit of any description or possible conclusions at this time.

Since the corroding surfaces of buried metallic pipe lines consist of anodic areas, electrically connected through the metal to other areas which are cathodic to them, with respect to the electrolytic portion of the circuit; and since pipe fittings and service connections frequently are made of, or are coated with, metals having a different position in the electro-motive-series from that of the iron or steel of which the main is constructed; a laboratory method of testing based largely upon the reported researches of U. R. Evans and E. S. Hedges was devised to measure the galvanic electrolysis of thin metal sections, imbedded in samples of moist earth to be tested for their relative corrosivity.

The test for galvanic electrolysis of thin metal sections by corrosive

soils makes use of the potential differences between dissimilar metals in contact with solutions of soil electrolytes. The unbalances of electrolytic concentration cell potentials thus created are typical of the unbalances of potentials between the anodic and cathodic metal surfaces exposed to soil corrosion in a system of underground pipe line and cable networks. No external artificial electrical potential is applied in this test; therefore, it is believed that the laboratory conditions imposed are representative of the electrolytic conditions which actually exist in the field under ordinary circumstances.

The tests made to date on thin sections of mild steel indicate a definite trend for the electrolytic displacement of metal, due to chemical attack by corrosive soils, to follow a mathematical curve. The corrosion rate is uniform at first, the slope of the curve depending on the chemical activity of the soil under test. After some time has elapsed and a protective film of corrosion products has formed on the exposed surface of the metal test specimen, the corrosion rate decreases and the slope of the plotted curve becomes less steep. With still further lapse of time, the protective film breaks down and the corrosion rate again increases. This sequence is repeated in cycles of somewhat varying duration, succeeding cycles apparently covering a much longer period of time than the first. Using thin sections of mild steel as anodes, galvanically coupled to cylindrical copper container cathodes, about forty-eight hours are required to determine the trend (the slope and characteristics of the plotted curve) of the complete first cycle for the soils tested thus far. Successive cycles appear to follow the same general trend, but cover longer periods of time. Different series of tests have been run for from one to fourteen days. Three different metals have been used as anodes, and two different metals as cathodes.

A special test to determine the efficacy of a sand blanket for protection of pipe buried in severely corrosive soils (the sand blanket also used, in practice, to prevent rupturing of protective coatings in soils which are both severely corrosive and produce severe soil stress) has been under way for some months. Six foot lengths of "sand cast," and of "metal mold centrifugal cast" pipe are being used in this test. A specially constructed box with a horizontally laid copper plate near the bottom, to serve as a common potential contact with corrosive earth contained in the box, was built to enclose pipe and earth. The box can be left open on top, or covered as weather conditions vary. The soil used in this test is one of those classified as "Severely Cor-

rosive." It is a soil that has caused severe graphitic corrosion of cast iron, and has proved severely corrosive to other structural metals.

TABLE I

Resistance between cast iron test pieces and copper plate

DATE	M.M. BARE, OHMS	S.C. BARE, OHMS	M.M. 3″ SAND, OHMS	S.C. 3″ SAND, OHMS	M.M. 6″ SAND, OHMS	TEMPERATURE AND MOISTURE CONDITIONS
2/ 5/37	46	41	175	140	203	Warm and moist
3/ 5/37	31	28	137	121	159	Warm and moist
3/26/37	37	35	154	128	172	Cool and wet
4/16/37	35	31	206	123	163	Cool and moist
5/ 7/37	36	31	201	122	172	Warm and dry
5/28/37	39	33	267	137	200	Cool and damp
6/21/37	32	26	280	127	191	Cool and moist
7/ 3/37	31	25	273	127	192	Warm and moist
7/23/37	36	31	330	158	233	Hot and dry
8/ 6/37	38	32	327	158	239	Hot and dry
8/20/37	43	33	353	186	272	Hot and dry
9/ 3/37	46	37	397	222	390	Warm and dry
9/10/37	46	38	373	205	346	Opened for insp.
9/17/37	45	37	365	198	332	Warm and moist

Galvanic potentials between cast iron test pieces and copper plate

DATE	M.M. BARE, VOLTS	S.C. BARE, VOLTS	M.M. 3″ SAND, VOLTS	S.C. 3″ SAND, VOLTS	M.M. 6″ SAND, VOLTS	TEMPERATURE AND MOISTURE CONDITIONS
2/ 5/37	−0.412	−0.460	−0.270	−0.429	−0.375	Warm and moist
3/ 5/37	−0.480	−0.535	−0.286	−0.440	−0.377	Warm and moist
3/26/37	+0.502	+0.560	+0.225	+0.440	+0.360	Cool and wet
4/16/37	+0.488	+0.545	+0.230	+0.408	+0.355	Cool and moist
5/ 7/37	+0.480	+0.540	+0.220	+0.400	+0.350	Warm and dry
5/28/37	+0.468	+0.530	+0.226	+0.400	+0.340	Cool and damp
6/21/37	+0.450	+0.530	+0.250	+0.405	+0.340	Cool and moist
7/ 3/37	+0.440	+0.530	+0.260	+0.415	+0.340	Warm and moist
7/23/37	+0.430	+0.530	+0.270	+0.420	+0.340	Hot and dry
8/ 6/37	+0.425	+0.525	+0.265	+0.415	+0.335	Hot and dry
8/20/37	+0.423	+0.522	+0.275	+0.414	+0.335	Hot and dry
9/ 3/37	+0.425	+0.517	+0.265	+0.412	+0.330	Warm and dry
9/10/37	+0.425	+0.518	+0.270	+0.410	+0.330	Opened for insp.
9/17/37	+0.420	+0.510	+0.295	+0.410	+0.325	Warm and moist

One length of bare metal mold pipe, and one of bare sand cast pipe is buried directly in contact with the corrosive soil; one length of metal mold pipe, and one of sand cast pipe is surrounded with a

three inch blanket of river sand between the metal and the corrosive soil; and one length of metal mold pipe is surrounded with a six inch sand blanket. Redwood plugs were driven into both ends of the 6-inch diameter by six foot lengths of cast iron pipe used in this test.

The Corfield Williamson nipple and can test showed: Sand used for blankets lost 0.220 gram (slightly corrosive). Sand from top of pipe after nine months lost 0.321 g. Sand from bottom of pipe after nine months lost 0.238 g. Soil from below blankets after nine months lost 4.262 g.

The complete unit of corrosive soil, copper plate, sand blankets, and buried test pieces has been repeatedly put through a series of wet and dry cycles. Distilled water is poured over the earth contained in the box to wet it, then allowed to dry out in the sun, at periodic intervals. During the rainy season, a cover is put over the entire unit to prevent an excess of moisture beyond saturation. Periodically, resistance measurements are made between the test pieces and the buried copper plate; and the galvanic potentials between the test pieces and copper plate are recorded. Some of the data obtained to date are given in table I.

PIPE LINE PROTECTION

The serviceable life of any pipe line can be defined as the number of years of service it will give without failures other than, perhaps, an occasional leak here and there. When the cost of repairs approaches the cost of replacement, the serviceable life of that portion of the pipe line is completely ended. The objective of protection engineering is to increase the serviceable life of the less favored portions to the long-life average of those portions suffering least depreciation. From the corrosion standpoint, this may be accomplished by special applications of protective coatings of tested quality, sometimes coupled with "Cathodic Protection" when adequately engineered to prevent creation of further hazards to neighboring substructures. Those portions of the pipe line exposed only to the slightly or mildly corrosive action of non-corrosive soils do not need this extra protection; consequently extra expense for pipe protection where corrosion is negligible cannot be justified. It is more economical to concentrate expenditure of funds allotted for protection in the areas of severely corrosive soils. The protective film of iron oxides formed on the surface of the pipe metal can be relied upon to give ample protection to pipe buried in slightly corrosive soils.

CATHODIC PROTECTION

Where "cathodic protection" is applied, insulating joints should be installed to isolate the coated from the uncoated portion of the line. Insulating joints should also be installed to divide the coated portion of the line into segments, thus to make control of the cathodic potential applied at any point feasible. Care and caution must be exercised, that additional corrosion hazards be not created for adjacent or inter-connecting underground pipe or cable networks. Every application of "cathodic protection" should be investigated as a separate unit and so treated. Otherwise, concentration of corrosion at high resistance joints may ensue, and other interests jeopardized. The Bureau of Water Works and Supply regards "cathodic protection" in much the same light as it does the grounding of telephone cables to water pipes for noise control—as a subject to be handled on the merits of the individual case, after data have been obtained to enable the parties concerned to arrive at an intelligent and mutual decision.

The possibilities for inter-change of electrolytic currents are so complicated, and so many different interests are apt to be involved, that we believe the problem can be adequately solved only by a committee of representatives of all the interests concerned. We believe this committee should logically be the local Electrolysis Committee. It is an electrolysis problem, no matter what viewpoint is taken. We believe that any inter-system electrical ties for cathodic protection should be made only after competent engineering surveys have been made; after the data have been analyzed, mutually passed upon, and the work contemplated has been concurred in by the committee; and then made specifically at each location by individual subcontract between the parties directly concerned, under a blanket form of agreement relative to such installations.

MAPPING CORROSIVE SOIL AREAS

Soil corrosivity maps aid designing engineers and construction superintendents in routing underground structures to avoid the most severely corrosive areas, and in determining adequate economical protection for those portions which unavoidably must pass through corrosive soils. Actual corrosion experience, wherever such data are available, is the surest guide to what may be anticipated in the future in each location; therefore, corrosion experience maps of the areas traversed by underground water mains have been prepared. These

maps are constantly built up and added to as new data is accumulated.

Modern methods of pipe protection, and new metallurgical compositions of structural metals, point to a probable increase in the expectancy of serviceable life for buried pipe lines. However, a prolonged wait for corrosion experience with these newer materials to serve as the immediate guide to their adequate and economical use in the various soil areas would postpone and retard comprehensive development. Therefore, scientifically compiled and correlated test data maps are an essential adjunct to corrosion experience maps. Reasonably reliable predictions of what the corrosion experience of the future *will be* can be made now instead of after years of waiting, by an intelligent study of the factors contributing to soil corrosion.

All of the various methods of soil testing used by the Bureau of Water Works and Supply of the City of Los Angeles have been selected and standardized with the objective of preparing reliable maps to show the relatively corrosive soil areas. These maps serve as a guide in the routing of pipe lines and in preparing specifications for adequate protection in those areas where protection against corrosion is necessary to assure an economical service life. Correlations between corrosion experience maps, soil corrosivity data maps, and the United States Bureau of Soils Maps have been studied with this objective. Sufficient data have not yet been accumulated for our maps and correlations to be regarded with finality, but very definite trends are indicated by them. The tendency is for the adobes and clays, especially those with noticeably high alkali content, to be most severely corrosive of the local soils. The loams and sandy loams are less corrosive than the adobes and clays, ranging down the scale to the well drained fine sands which are the least corrosive of our soils. Soils of marine laid origin, and those geologically new and unweathered, are among the most corrosive soils.

Soil corrosivity surveys are conducted along the routes of all of our major pipe line installations. As a survey progresses, the various test data obtained are visually portrayed on cartograms, similar to figure 2, and the several corrosivity indications are correlated and projected as a composite soil corrosivity index. The cartogram is used as a guide to adequate and economical pipe line protection.

A LABORATORY SOIL CORROSION TEST

By Vladimir A. Grodsky

It is a well known fact that buried pipe lines are affected by corrosion. But, although the degree of corrosion of different ferrous pipes is more or less the same in a given soil, the corrosiveness of various soils differs greatly. This has been conclusively proven by the extensive tests which were conducted under the direction of the National Bureau of Standards. These tests were run over a period of over 12 years and are not concluded yet. Thousands of pipe samples were buried in many parts of the U. S. in typical soils. The samples were excavated after certain periods and the corrosion losses, as well as the character of corrosion, determined.

There are soils such as Bell Clay, Mahoning silt loam, Merrimac gravelly sandy loam, Ontario loam and most of the sandy soils, which are comparatively harmless, while soils such as Susquehanna clay, Tidal Marsh, Peat, Merced silt loam, Hempstead silt loam and others are highly corrosive. Of course a very large number of soils can be placed (in respect to their corrosiveness) somewhere between these two extreme groups. For comparison we will give the average rates of loss of weight and average rates of maximum pitting for 12 years old specimens of wrought ferrous pipes in two soils, one only slightly corrosive, the other very corrosive. An average for all investigated soils is also given.

NAME OF SOIL LOCATION	LOSS OF WEIGHT OUNCES PER SQ. FOOT PER YEAR	MAXIMUM PITTING MILLS PER YEAR
Merrimac gravelly sandy loam, Norwood, Mass.	0.120	2.10
Tidal marsh, Elizabeth, N. J.	1.306	7.76
Average of all investigated soils	0.5615	5.66

The Bureau of Standards tests have also established the fact that the rate of corrosion is related to the acidity of the soils. For in-

Contributed record of research by Vladimir A. Grodsky, Metallurgical Engineer, U. S. Navy Yard, Washington, D. C.

stance, for the just mentioned soils the total acidity (milliequivalents per 100 grams of soil) is 12.0 for the Merrimac soil and 30.8 for the Tidal Marsh. But it must be also born in mind that the acidity or alkalinity differs not only for various soils but also for different horizons of the same soil and this fact may obscure the results of tests.

The pH value of soils usually varies from 3 to 7.5. Soils with the lower pH value, somewhere around 4, are more acid and more corrosive, than soils less acid or even slightly alkaline with a pH about 7.

LABORATORY CORROSION TEST

In earlier tests pieces of iron pipe weighing several pounds were used for laboratory tests but it was hardly possible to determine the corrosion losses in grams and fractions of grams for samples weighing a pound or more. Furthermore, these pieces of pipe were buried in large boxes and the soil moistened occasionally. Of course no consistent data could be obtained by this method. After some experimenting it was found that the most suitable iron for soil corrosion tests was in the shape of pieces of sheet steel .004 inches thick, the so-called shim steel.

A disk was cut out with a pair of scissors and placed in a small laboratory bottle partly filled with soil to which a certain amount of water was added (about the quantity of water necessary to produce a maximum corrosion effect). At first it was thought that the test should last a considerable length of time (1–2 weeks) but later it was found that reliable data could be obtained after corrosion lasted for only 20 hours. A twenty hour test was considered more convenient than a test lasting 24 hours because the samples could be set up in the afternoon, weighed next morning, set up in the afternoon and so on.

The procedure is as follows: a filter paper disk E_1 is placed on the bottom of a laboratory bottle A (Fig. 1) and 1 c.c. of water from a burette is poured over the paper. Then 2 c.c. of the test soil is distributed evenly with a spatula over the surface of the filter paper. Next the steel disk is placed on top of the soil. Care should be taken not to touch the surface of the disk with fingers. The disk should be gently tapped down so as to be everywhere in contact with the soil. Another 2 c.c. of the test soil is put on top of steel disk C and covered with the second filter paper disk E_2. The rest of the amount of water (in addition to the 1 c.c. already used) necessary

to produce the maximum corrosion effect in the soil sample tested, is poured from the burette over paper disk E_2.

The purpose of the paper disks E_1 and E_2, below and above the soil D, is to distribute the water more evenly. Of course the volume of water required to saturate these paper disks must be taken into consideration and added to the amount which is necessary to produce maximum corrosion. In our tests 0.4 c.c. of water was used for both filter papers. The upper paper disk E_2 and with it the soil are tapped down with finger tips and, after replacing cover B, bottle A is set up in a place protected from changes of temperature. Next

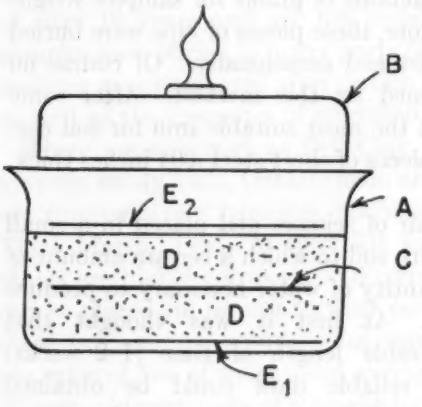

FIGURE 1

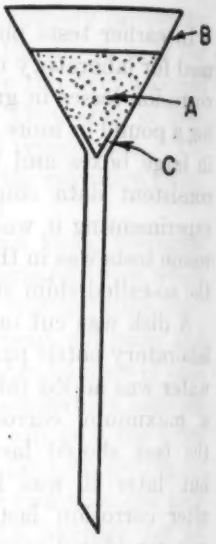

FIGURE 2

day the steel disk is removed from the bottle and soil and rust rubbed off from the disk with fingers under a stream of water from a faucet. After weighing and determining the loss the same disk can be used again which saves one weighing in each test.

MOISTURE CONTENT A DETERMINING FACTOR

We know that two factors are most important for the corrosion process—oxygen and moisture. Soil corrosion differs materially from atmospheric corrosion insofar as chemical and physical properties of the soil are very important for the progress of corrosion.

When the soil is perfectly dry no corrosion of iron buried in it will take place, no matter how highly corrosive the soil is. But as soon as moisture appears, corrosion will begin, not only because particles of the soil are now able to start some chemical reaction, but also because oxygen of the air reaching the surface of the metal through voids in the soil is instrumental in the formation of electrochemical cells in the presence of moisture. It was found by the disk tests that by adding an increasing volume of water to a perfectly dry soil, corrosion will also slowly increase till a certain moisture content is reached. Then, with the addition of more water, corrosion will increase rapidly reaching a maximum which usually is much greater than the corrosion losses produced with less water. When still more water is added the corrosion losses will drop just as fast and soon will only slightly exceed the losses in comparatively dry soil. For instance, the loss of weight of disks (of the size given above) during a period of 20 hours was for:

	MERCED SILT LOAM	CECIL SILT LOAM
With 15% water added.....	0.0063 gr.	—
With 25% " "	0.0076 "	0.0020 gr.
With 30% " "	0.0076 "	0.0048 "
With 35% " "	0.0110 "	0.0071 "
With 40% " "	0.0078 "	0.0067 "
With 45% " "	0.0049 "	0.0056 "
With 50% " "	0.0023 "	0.0056 "

In most of the soils tested the maximum corrosion effect could be produced when the moisture content of the samples was between 30 per cent and 45 per cent. It is believed that this critical moisture content varies for different soils in accordance with their saturation point, which we will discuss later. The corrosion curve peak could always be observed at the same moisture content in samples of the same soil. This means that corrosion losses of disks buried in different soils can be compared, giving a corrosion characteristic of these soils, provided the duration of corrosion is the same, the size of soil particles is about the same and the volume of water added to each soil is producing a maximum corrosion effect for that soil.

But how can this rise and drop of corrosion losses, caused by changes in the moisture content, be explained?

Every soil is an agglomerate of particles of various size. Some of the particles can absorb moisture (clay, organic matter) some others

cannot (sand). When water is gradually added to dry sand surrounding a piece of iron it will fill up the voids between the sand particles, beginning at the bottom. Even a small volume of water will be sufficient to close up the capillaries next to the metal surface, preventing the access of oxygen of the air to the iron. Only a slight corrosion in sand will be the result.

In the case of clay, the soil particles absorb moisture and when there is no large excess of it, the voids and capillaries between the particles remain still open and oxygen has access to the surface of the pipe—corrosion will result. With the increase of the moisture content, however, the clay particles begin to swell and will close up the voids. This explains why corrosion in pure clay, although higher than in sand, is still not excessive.

When soils contain clay and sand (loam soils, silt loam soils) a greater corrosion effect may be expected, because sand helps to keep open the voids and capillaries in a moist soil of this kind.

It is logical to assume that the maximum corrosion effect will occur when all the soil particles, which can hold moisture, are saturated and a certain volume of free water is in the capillaries and voids between the particles, while the passage of air is still not blocked off. Of course when the voids and capillaries are small the surface of the buried pipe is better protected from oxygen than in a case when the passages are large and the soil is made up of big particles. In order to make the corrosion tests dependable it is therefore important that the soil particles in all the test samples are of a uniform size. For the disk test a 60 mesh sieve was mostly used. To determine the volume of water required for the maximum corrosion effect we must find the volume of water necessary for saturating the whole soil sample and also the volume of water which will fill the voids and capillaries between the particles of the sample. Deducting the second volume from the first we will find the volume of water needed to saturate just the soil particles. A slight excess of water over this amount will produce the maximum corrosion effect for that soil sample.

SATURATION POINT OF SOILS

The following procedure for determining the volume of water which will saturate the soil particles of a sample was considered sufficiently accurate.

A handful of soil, broken up into small lumps, is spread on a sheet

of paper and left so over night. Next day the soil sample is pounded in a mortar and put through a 60 mesh sieve. 4 c.c. of the soil which passed the sieve are put in a laboratory 60° small funnel B. The opening into the stem D is closed by a small filter paper disk C. Water is then poured from a burette on soil A and it gradually wets the soil down to the filter C. As soon as all the soil particles are saturated and all the voids between the particles filled up, water will appear in the stem of the funnel.

Taking 4 c.c. of pure quartz sand, having particles of the same maximum size (60 mesh) as the soil tested, we can easily find by this funnel test the volume of voids between the sand particles, because no moisture will be absorbed by the particles themselves and the saturation point for sand will be equal to the volume of the voids. By deducting this figure from the saturation point of the soil sample (4 c.c. and 60 mesh) we will know the volume of water needed for the saturation of the soil particles. As it was already said before, a slight excess of moisture over this volume will be the amount of water which will produce the maximum corrosion effect for that soil.

When determining the volume of voids in clays, where the particles are much smaller, the 60 mesh sand will be too coarse and a very fine sand has to be used.

The obtained figures checked well and the results could be repeated. Usually three corrosion tests of the same soil sample were set up. One with the water volume determined by the above procedure and the two other tests with a somewhat larger and somewhat smaller volume of water. The highest corrosion result was then used.

PREVENTING OF PIPE LINE CORROSION

Having determined the saturation point for a large number of soils it became possible now to make tests with neutralized soil samples. Parallel disk tests for a large number of corrosive soils were set up, one test without any neutralizing agent, the other with such an agent, the volume of water added being the same in both tests. Only traces of corrosion could be observed in tests where the soil was neutralized. For instance, when various amounts of lime were added to a sample of Susquehanna clay the following losses of weight of a disk (of the size given above) could be observed:

7.1% of lime	No loss of weight
5.4% " "	0.0003 gr.
3.7% " "	0.0067 "
1.88% " "	0.0113 "
0.95% " "	0.0144 "
No lime	0.0164 "

The duration of the test was 20 hours and the volume of water added to the samples was such as to produce the maximum corrosion effect for this soil.

It was found that the theoretical amount of neutralizer was not sufficient. Corrosion would stop only when the amount added was about three times greater than the theoretical requirement.

SUMMARY

A short, direct, accelerated laboratory corrosion test is proposed. Sheet steel .004″ thick is used, from which 1.6″ diameter disks are cut. The disks are placed in a 2″ diameter laboratory bottle containing 4 c.c. of a dry soil sample. An exact volume of water is added. A method for determining the volume of water required for a maximum corrosion effect is described.

These corrosion tests were used to prove that corrosive soils to which alkali was added lost most of their corrosiveness.

PROTECTION OF METALS TO RESIST CORROSION

By A. A. M. Russell

The metals of primary importance to the water works field are those of the ferrous type. The ferrous metals in general use are wrought iron, pure iron, cast iron, steel and the various steel alloys. Each have definite physical characteristics that commend them for use in construction to resist external forces but unfortunately all are prone to deterioration. The rate of deterioration of these metals is a function of the type of exposure whether it be in air, alternately wet and dry or entirely submerged. In the "Fifteenth Report of the Committee of the Institution of Civil Engineers" we note this statement: "On the whole there appeared little to choose between the wrought iron and ordinary carbon steels used in this research in their mean resistance to the various types of corrosion studied. The carbon steels proved superior to wrought irons in their resistance to aerial corrosion while in fresh water there was nothing to choose. The cast iron resisted aerial corrosion exceedingly well comparing favorably with the best alloy steels tested in this research. They also resisted fresh water reasonably well. High chromium steel of the type containing 13.6 per cent of chromium satisfactorily resisted atmospheric and fresh water corrosion. The addition of 3.75 per cent of nickel to 0.31 carbon steel enhanced markedly its resistance to aerial and fresh water corrosion. Steel containing 36.6 per cent of nickel proved highly resistant to all forms of corrosion. It was the most resistant of all the metals tested." It will thus be seen that the alloys were the most resistant but unfortunately initial costs will be excessive.

Another type of metal that may be used in water supply work is that of the brasses and copper. In connection with the use of this metal with that of metals of the ferrous type, I would like to warn

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A paper presented before the California Section meeting at Sacramento, October, 1937 by A. A. M. Russell, Testing Engineer, Board of State Harbor Commissioners, San Francisco, Cal.

you of the dire results of these two metals in contact. No doubt you have noticed such metals in contact with disastrous results to the ferrous metal. With this combination in the presence of an electrolyte we are setting up a small battery that will destroy the ferrous metal in time. One should study the electro-chemical series of the metals before connecting two dissimilar metals. Quoting again from the report of the Institution of Civil Engineers, we find these statements: "Placing dissimilar metals in contact did not lead to any pronounced results in the aerial tests. In all the other tests it was found that—

(a) Ordinary steel in contact with wrought iron was partially preserved at the expense of the wrought iron.

(b) Chromium steel and high nickel steel in contact with ordinary carbon steel were protected from corrosion at the expense of the latter."

You will thus see that even metals of the same general type exert an influence that is conducive to the destruction of one of the metals under favorable circumstances.

Regarding the cause of the deterioration of metals, it is not within the scope of this discussion to enter into the various theories of corrosion. It is immaterial whether one believes in the carbonic acid theory, electrolytic theory, the oxygen theory or the concentration of the hydrogen ion, it is a foregone conclusion that one ends with a mass of rust unless protective measures are taken. No protective measures are a positive cure for corrosion. Periodical inspections must be made to check any deterioration of this protection.

The first protective measure is the use of a protective metal over the ferrous metal. Of this type we are all familiar with the protection afforded by the use of zinc. There are a number of methods of applying this metallic coating, but it has been our experience that there is only protection given to the metal when the applied coating is of appreciable thickness. The only method of galvanizing that appears to give a satisfactory coating is the hot dip but even with this method of coating a minimum amount of spelter should be specified in order to be assured of an adequate coating. On heavy sections I would say that the minimum coating should be at least three ounces of spelter per square foot of metal. One of the latest developments in this field is the metal spray. There is no doubt a place in the industry for this method of metallic coating especially to renew coatings on structures in place, but we should not lose sight of the thick-

ness of metal applied whether on new or old work. The metal spray is not limited to the use of zinc alone but lead, copper and brass can be applied as a protective coating. There is no doubt that the application of a protective coating will give added life to ferrous metal under some conditions, but we also meet with other conditions that give results that would hardly justify the application of a metallic coating. Due to the high cost of the applied metals it appears that in many severe conditions of corrosion of the applied metal that we would be justified in using the money that would be spent for coating in increasing the thickness of the member. These conditions would be found in a situation where the active destructive agent is of an acid nature. By increasing the thickness of the member an added life will be given to the structure and this can be still increased by the application of some cheaper coating.

Another type of protection is that in which concrete is used to protect the ferrous member. In using this type we are assured of excellent results as long as we have an alkaline condition surrounding the metal. In order to maintain this hydrate condition it is essential that the concrete be of maximum density and that the covering be continuous. In this connection we have made a very extensive study of the condition of the reinforcing bars and structural steel that has been encased in concrete for years. We found that wherever the hydrate condition existed there was no sign of rusting of the metal, but where this hydrate had been changed to carbonate by the action of carbon dioxide there would always be more or less corrosion. It is also essential that the concrete coating be also of adequate thickness. One of the steel companies has produced a pipe with the inside lined with cement. There is no doubt that under conditions where the system carries corrosive waters such as salt water there might be some justification in using this type of carrier in preference to the black pipe. Like the coating of the ferrous metal with a protective metal, this system of protection is expensive and is only justified under severe conditions of corrosion.

Another type of protection that is used extensively is that of the hot hydrocarbon variety. In this class we have the specialized enamels as well as the lowly asphalt or coal tar. In using this type of coating we are relying to a great extent on the thickness of the applied coat. In the west we are more familiar with the asphalts than the coal tars. It has been our experience in using these hot coatings that there is a very great variation of the coating when it is applied.

Some portions are ductile while other portions are hard and brittle. It appears that we are here faced with human frailty, a factor difficult to evaluate in our engineering operations. A material as delivered may be well within the specifications but when it is brought on the work but, applied, we may note a distinct variation in the type of coating. Many of these variations can be traced to the heating of the material. If the critical temperature of the coating is around 250°, then all temperatures above this will tend to drive off the volatiles and the resulting coating will vary in hardness according to the amount of heat above this temperature and the duration of heating. The use of thermostatic control on the kettle and the use of accelerators on the men are both in order to make the heat less variable in the pot and cut down the duration of heating. As long as a hydro-carbon coating is continuous it will afford excellent protection to the metal, but if it is non-continuous, it produces one of the most dangerous types of corrosion. If there is a break in the film, either through abrasion or due to a bubble breaking that reaches the metal, then with even a weak electrolyte we are setting up a small current of electricity. The action is at the junction of the hydrocarbon and the metal and this will spread in this area at a fairly rapid rate. A casual inspection will show that the film is intact but if one attacks the coating with a sharp instrument it will be found that there is a mass of rust between the steel and coating.

The last type of protection will be designated as brushing and may or may not contain a vegetable oil as the vehicle. In dealing with this type, I should like to divide paints into a priming coat of paint and a finish coat of paint. As a primer we are all familiar with red lead and for this purpose we cannot make a better choice than this material. There are advantages attached to the use of a chromate for priming purposes but as a rule such a paint will be more expensive unless one will allow the use of extenders in the pigment. Either paint should have a raw linseed oil vehicle with only enough thinners to cut the greasiness of the oil, and the drier content only enough to give a slow drying paint. There should be no extenders or other pigments added to the priming coat of red lead as exposure tests have shown that such additions will cause premature failures of the priming coat. I would also suggest that the true red lead content of the pigment be not less than 94 per cent. It is our practice to use a red lead paint that weighs between 24 and 25 pounds to the gallon. This can be obtained by using 20 pounds of dry red lead,

⅝ gallon of raw linseed oil, and 1 pint of thinner and drier. The resultant paint is thin enough to spread readily and yet is not thin enough to run, after it has been applied to the metal.

Red lead makes a good priming coat, but, as a finish coat to resist the elements, it does not measure up to some other paints. In dealing with the finish coats, I would like to divide these into two classes, (1) a paint that is good for atmospheric corrosion, (2) a paint to resist abnormal conditions, such as water, acids, gases.

In the first class will fall paints with a vegetable oil vehicle and pigments that will give the desired architectural effect as all these structures will be above ground. For this type of work we are confronted with the question of utility as well as the architectural effect. After numerous tests extending over a number of years, we have come to the conclusion that a coat of graphite paint over a red lead priming coat will give longer service than the use of any of the other paint pigments. In using graphite as the pigment we were confronted with dark colors such as black, slate, green or red, until a few years ago. There is now an aluminum graphite paint made that can be used to advantage. We have utilized this type of graphite for painting of steel inside the dock sheds. By using this light colored paint we have increased the amount of light and still have the protective qualities of the graphite. If colors other than those mentioned are desired, pigments must be used, but I would still use graphite as a second coat and the desired color or shade as finish coats. I say coats, because it may be necessary to apply more than one coat to attain the desired architectural effect.

Into the second class of finish paints will fall the hydrocarbons as it is impossible to use oil paints with satisfactory results. These paints unlike the before mentioned hydrocarbon enamels, will be applied cold. Experience has demonstrated to us that the coal tars will give us much better results than asphalt. These results have been substantiated by tests made in England. In using a coal tar paint the tar should be dehydrated and the resulting paint should not be too thin in consistency. The consistency should be heavy enough to leave an appreciable thickness of coating on the surface. A satisfactory paint shows a residue of fifty per cent when the distillation temperature is carried to 350°C. The actual analysis of a hydrocarbon paint is such that when it is completed you are none too sure that the substances found are constituents of the paint, and we find that requiring a minimum residue of 50 percent will give a paint of required consistency. This finish coat of coal tar is applied to

protect the lead priming coat and should be continuous and, as stated above, of adequate thickness to be assured of protection of the metal.

In selecting a paint for abnormal conditions, we are required to make actual exposure tests of the different materials. One or two of the best paints are selected and subjected to actual working conditions. The performance of these materials is watched for a long period and the best material is selected. This is then used as a standard and any materials offered as an equal must be tested in a similar manner before it is accepted. We ask that a service test of three years must be given before acceptance. By testing in this way we are not closing the door to a material that may be better and we are also protecting ourselves from materials that are inferior to the standard.

Having selected the paint, it is just as important that the surface be properly prepared to receive the paint. If the metal is new, one should be sure that all loose mill-scale is removed. This can be accomplished either by wire brushing or by sandblasting. It is our practice only to wire brush to remove loose mill-scale and superficial rust before the priming coat is applied. In using the sand blast, no doubt more of the mill-scale will be removed than is removed by exposure and wire-brushing, but one should also be careful that the pits caused by the abrasive material are not too deep as other troubles will develop. If the steel has been in place for some time and has acquired an accumulation of rust, then one must use a chipping hammer and sandblast before painting. It is essential that rusted steel be thoroughly cleaned before any paint is applied.

There is no method of protecting steel that will allow a job to be completed that is good for all times. There are bound to be weak spots in all methods of protection and it is these weak spots that cause trouble. Under normal conditions a *good* coat of the proper paint should give adequate protection for at least five years, but this length of service cannot always be relied upon. Periodical inspections should be made and an anticipated life assigned to the coating. The metal should be recoated before the corrosion has progressed to such an extent that layers of rust are being built up. If some such program is followed, costly sandblasting will be eliminated and, in many instances, one can renew the protection by touching up broken spots in the priming coat and applying a finish coat over the entire surface. Only eternal vigilance will keep the metal from excessive corrosion.

THE DOLLARS AND SENSE OF WATER MAIN CLEANING

By Clinton Inglee

In projected installations of transmission, feeder, and distribution mains the merits of steel, enameled cast iron, cement lined and transite pipe are weighed and that product best adapted to meet the conditions of service and the financial limitation is selected. More than ever before, interest is being shown by the water works profession in the subject of corrosion, its cause and prevention. The advances being made in water treatment and pipe fabrication should insure long years of efficient service in new installations.

However the water works operator who is looking toward efficient operation of his water supply facilities cannot afford to overlook conditions present in the existing water mains. Water treatment may serve to prevent further reduction in pipe coefficients, but will not increase present capacities unless slowly and with probable long periods of water discoloration. There have been instances where a radical change characteristic of the water has caused a more or less rapid sloughing off of existing deposits or corrosion, sometimes to the discomfort of the operator and consumer and with little improvement in capacities. Sometimes changes in treatment may be responsible for increased corrosion, as in the case of a mid-wastern plant where there was apparently no tendency toward rapid tuberculation until about five years ago when aeration was undertaken. Since then the corrosive action has been so great that insufficient capacity requires early remedial measures.

The capacity of a line is best indicated by its coefficient. Standard tables give such coefficients for new pipe, those in most general use being Hazen & Williams. The loss of head, or friction loss for a measured flow of water determines the coefficients for both new and old mains. Age alone does not determine the drop in coefficient, as the reduction in capacity will depend upon the activity of the water carried. Reduction in capacity and lowering of coefficient may be due to one or more of several causes.

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* A paper presented before the meeting of the Kentucky-Tennessee Section at Louisville, March, 1938. The author, Clinton Inglee, is President of the National Water Main Cleaning Co. of New York, N. Y.

Hard waters will cause incrustation on the interior walls of pipe, but usually at a slow rate; this coating is apt to be extremely hard and difficult to remove. Excessive lime treatment will also cause incrustation—sometimes at a rapid rate. If this can be controlled the deposits will form a protective film and be beneficial rather than

PLACE	COEFFICIENTS					PER CENT CAPACITY INCREASE
	Diameter	Williams and Hazen		Chezy		
		Before	After	Before	After	
Stanford U.—Palo Alto, Cal...	12	65	124			90
Amityville, N. Y.....	8	84	132			57
Bayshore, N. Y.....	6	35	111.5			218
Brightwaters, N. Y.....	6	42.6	114.5			168
Westhampton, N. Y.....	4	31.6	112			252
Brightwaters, N. Y.....	4	43.3	119			177
St. Louis, Mo.....	6	84	115			37
" " "	12	89	119			34
" " "	36	80	117			46
Gettysburg, Pa.....	8	71.5	122			71
Omaha, Neb.....	36	68	121			78
Kansas City, Mo.....	16	68	130			91
" " "	20	56.5	120			112
" " "	24	74	126			70
" " "	30	70	122			74
Utica, N. Y.....	24	90	131			45
Boston, Mass.....	16	42	139			230
Fort Thomas, Ky.....	10	80	120			50
Cincinnati, Ohio.....	36	59	136			130
Mt. Vernon, N. Y.....	4			26.7	107.8	304
Meriden, Conn.....	12	62	130			110
White Plains, N. Y.....	6	87	122			40
New Rochelle, N. Y.....	6	23.5	120			410
" " "	10	52	110			110
Carbondale, Ill.....	8			44.6	101.5	127
Monterey, Cal.....	12	74	121.3			64
Baytown, Texas.....	24	70	128			83

harmful because a light lime coating will prevent "red water" trouble and corrosion. But if the deposition is not controlled, hard water may so reduce pipe capacity that cleaning soon becomes imperative. Illustration 1 shows what may happen when excessive lime treatment is carried on.

Soft and acid type waters, by breaking down pipe coatings, act on

the metal in the pipe and corrosion takes place. With active waters it may be but a few years when pipe capacities are so reduced as to require cleaning or replacement. It is not unusual to find 4- or 6-inch pipes reduced to one-third of original capacities and larger mains reduced to one-half capacities because of this tuberculation or cor-

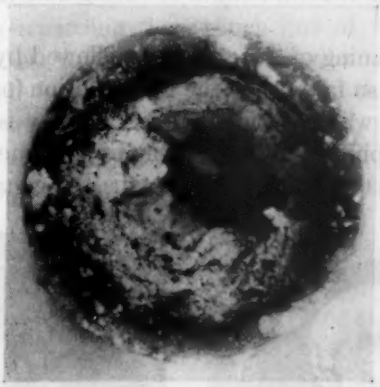

FIG. 1

FIG. 2

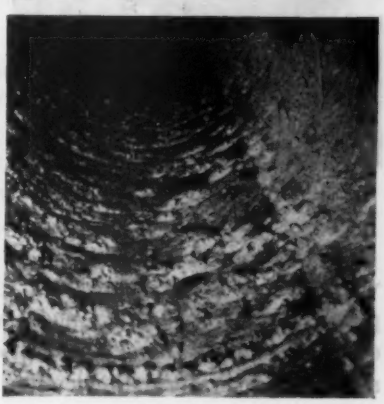

FIG. 3

rosion. Illustrations of corrosion in cast iron and steel mains are shown in cuts 2 and 3 respectively.

In localities where water is of high turbidity and where mains were in service many years before filtration was adopted, deposition of sediment took place. Frequently water mains are found in which one-fourth to one-half of original capacity is lost due to the com-

bination of mud deposits and tuberculation. A condition of this kind is shown in cut 4.

Pipe capacity may be also reduced, and offensive tastes and odors caused by organic growth such as crenothrix, gallionella, etc. This condition is not so common, however, as incrustation, tuberculation or sedimentation. A combination of silting and vegetable growth is shown in cut 5.

Mechanical cleaning of water mains, followed by intelligent water treatment, seems so far to offer the best solution for existing troubles and is warranted where an increase in capacity is desired; where a reduction in pumping costs exceeds the improvement costs; or where changes in water treatment are the cause of consumer complaints.

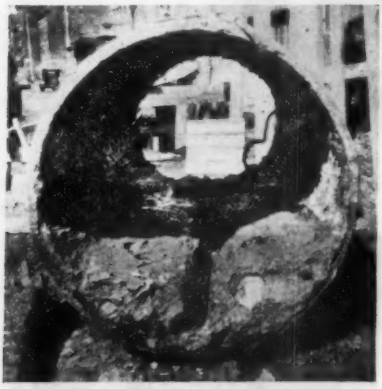

FIG. 4

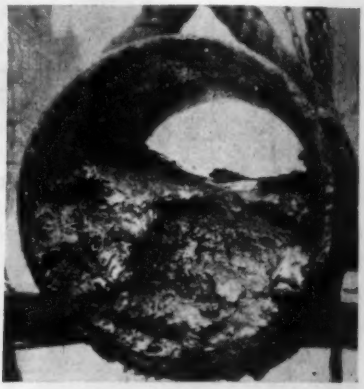

FIG. 5

New pipes can be installed, of course, but this is expensive. It involves the cost of tearing up pavements, opening long trenches, purchase of pipe, and inconvenience to consumers. The most economical and satsfactory solution to the problem is the adoption of a program of water main cleaning by which pipe can be restored to its original diameter and capacity.

In determining the diameter of main to be laid, the engineer tries to foresee the probable growth in population and the probable drop in capacity and plans the system for many years of service. In the installations he may have been limited by financial considerations and probably had to specify mains of smaller diameter than he desired. In many instances consumption has caught up or exceeded capacities. With the country becoming more air-condition-minded the matter of pipe capacities may well become acute.

An example in upper New York State is brought to mind. Here increase in consumption required that coefficients in the 16-inch and 24-inch feeders be not less than 105 whereas coefficients actually were from 85 to 100. These lines were cleaned and the coefficients were restored to 135 to 140. Now with improved water treatment, it is expected that high coefficients will be maintained.

The situation as regarding the 24-inch line of the Consolidated Water Co. of Utica, N. Y. has been quite fully discussed by J. Walter Ackerman at several water works meetings. In that instance until satisfactory water treatment was inaugurated, it was necessary to clean at frequent intervals to maintain the needed capacity. Mr. Ackerman now reports that with chloramine treatment coefficients well over 130 are maintained.

B. L. Ulrich as Superintendent of Water Works, Manhattan, Kansas, in a paper published in "Kansas Municipalities," included the pressure charts here shown. The first being the recorded pressures for one week previous to cleaning. The second shows readings for the week after the cleaning program was completed. The cleaning of about 8 miles of 4 to 10-inch pipe resulted in the maintenance of fairly uniform pressures of 70 pounds—a great improvement over the before-cleaning condition when pressures varied from 45 pounds to 70 pounds. This is not surprising when it is known that in the 10 inch line alone there were $2\frac{1}{2}$ inches of incrustation.

In Waco, Texas, W. H. Deaton, Supt., reported as follows: "We ran two tests on 3050 feet of 8-inch line. Before cleaning with the line entirely open except for 12 feet of 4-inch connecting on 4-inch meter, maximum flow through line was 500 gallons per minute. After running the cleaner through, this pipe under the same conditions gave us 800 gallons per minute." This line was cleaned in 1930. In 1937 Geo. J. Rohan, now Superintendent, reported that the pipe has stood up since the cleaning and that no trouble of any kind has been noted due to the cleaning.

In 1935 measurements on the flow through 4783 feet of 8-inch pipe cleaned at Yates Center, Kansas, indicated before cleaning with a pump ressure of 154 feet, a flow of 306 gallons per minute—after cleaning, with the pump pressure reduced to 106 feet, the flow was 450 gallons per minute.

At Baytown, Texas, Humble Oil & Refining Co. report that before cleaning 6,600 feet of 24-inch pipe the flow was 13,000,000 gallons per day with 72 pounds pumping head, while after cleaning the flow was 15,000,000 gallons per day with a pumping head of 62 pounds.

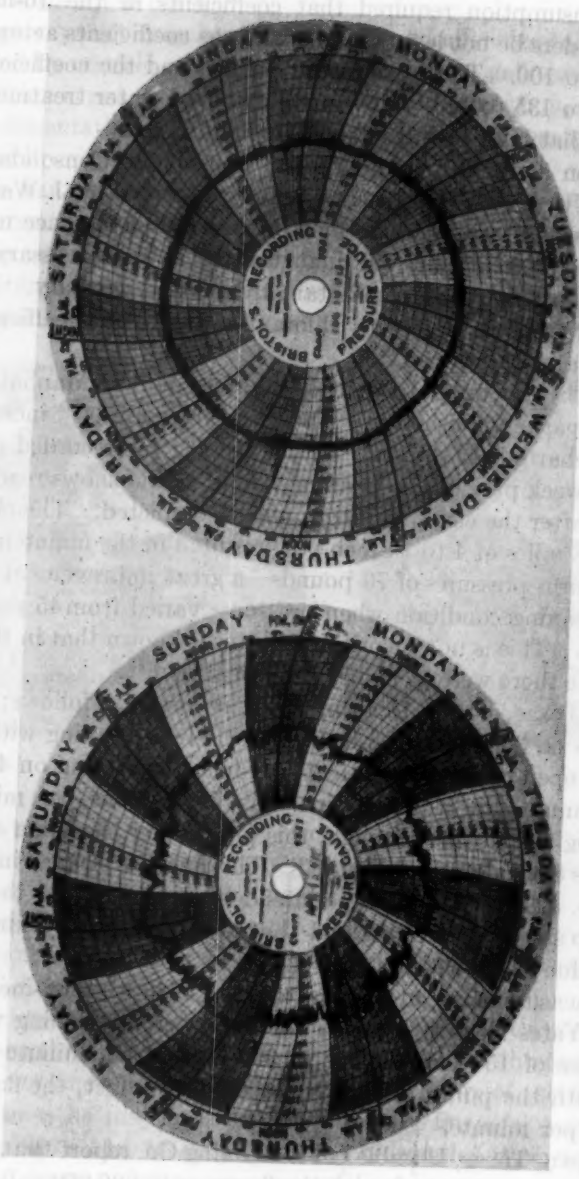

FIG. 6. RECORD CHARTS SHOWING THE DAILY DROP IN PRESSURE DURING PEAK LOADS BEFORE AND AFTER CLEANING MAINS AT MANHATTAN, KANSAS

A remarkable showing was made in Toledo on a particularly dirty 12-inch main. Before cleaning with a friction lost per thousand of 6.9 feet the flow was 550 gallons per minute; after cleaning with a friction loss of 4.4 feet per thousand the flow was 1,750 gallons per minute.

Numerous other cases might be cited where high coefficients have been obtained by the mechanical scraping of water mains and in not a few instances these high coefficients have been maintained by water treatment alone following cleaning or by the expedient of periodic cleaning with water treatment.

Where water is pumped through long lines and, through the building up of deposits or incrustation, friction losses are increased, then pump pressures must be raised or even booster pumps installed unless effective measures are taken to reduce the friction losses. The laying of new or parallel lines is even indicated where increased pump facilities are not practical. If material savings in pumping costs can be had or if the capital outlay for booster pumps and new lines can be postponed by a reduction of friction losses in existing lines, then certainly water main cleaning is justified.

In a small Maine community, the cleaning of its long 6-inch supply line resulted in a saving in pumpage expense of $28.00 per day. Here the cost of the improvement was more than paid for with the saving of 2 months.

Mr. Albert R. Davis, Supt. Water Department, Austin, Texas, reported as follows on the cleaning of 6,000 feet of 8-inch pipe: "The territory supplied by the above line was suffering severely from lack of water pressure due to the reduced carrying capacity of this line. After cleaning in 1931, pressure was restored to such an extent that it was not necessary to build an additional line into this territory until 1936. The construction work in 1936 amounted to approximately $20,000.00. Due to the cleaning, this expenditure was delayed approximately five years. Considering only interest on the investment at five per cent, we have saved $1,000.00 per year for five years, or $5,000.00 which is approximately five times what the cleaning cost."

At La Grange, Ga., a raw water line, (10,339 feet of 12-inch) was cleaned in 1930. G. H. Sargent, City Engineer, reported a saving in pumping expense of $200.00 per month. The saving paid for the cost of the improvement in about six months.

In Columbus, Ohio it was found necessary to lower a 36-inch line

parallel with an old 24-inch line. The capacity of the 24-inch line was so reduced that it could not carry the load while the 36-inch line was out of service and at first the laying of a temporary main at a cost of $4,500.00 was considered. But instead the 24-inch line was cleaned, and about 65 tons of lime incrustation removed, at a cost of approximately $1,800.00. It was then capable of meeting the requirements during the time the 36-inch line was out of service. The City saved $2,700.00 and now has a new 24-inch line as far as capacity is concerned.

In Amherst, N. S. as a result of cleaning at a total cost of approximately $6,100.00 an annual saving of $2,500.00 in fuel costs was experienced.

In Batavia, Ohio the average monthly pumping bill before cleaning was $205.00 while after cleaning it was reduced to $105.00 for the same amount of water pumped.

D. S. Wickwire, Supt. of the Water Department at Yarmouth, N. S. has this to say regarding the economical aspect of water main cleaning—"A 12-inch gravity supply line laid in 1881 with a total fall of 2.8 feet per thousand had become incrusted with tubercles on the inside so that the flow was reduced to 500 U. S. gallons per minute. This line was 8½ miles long. Our daily consumption was about 800,000 gallons per day and what we could not get through the 12-inch pipe was taken from an inferior and somewhat polluted source nearby. A parallel line was advocated at a cost of $75,000.00. With certain misgivings, I advised cleaning at a cost around $8,000.00. When the job was done we were getting 800 U. S. gallons per minute which supplies the town very well." This line was cleaned in 1928 and is still giving satisfactory service. The new line has not yet been laid and the saving of interest and charges on the capital investment for a parallel line has long since paid for the cost of the improvement.

Following the cleaning of the 14-inch and 16-inch supply lines for the City of Salisbury, N. C. the City Engineer gave this information—"This main consists of two units, one a force main, from the river to the sedimentation reservoir and the other a gravity main, from the reservoir to the filters. The gravity main had built up to the point where we were using a booster pump on this line averaging $125.00 per month. This will not be necessary now. The force main had also built up causing a low delivery on the pumps from the high head. The cleaning has dropped our over-all pumping cost $3.48 per million gallons."

In cut number 7 is shown a section of non-ferrous pipe reduced in capacity by a material, the chemical composition of which consisted of

	per cent
Ferric oxide	62.3
Silica	9.5
Miscellaneous	0.9
Volatiles	27.3

This analysis is very nearly like those given in a paper published in the Journal of the New England Water Works Association (June, 1932) by Reddick and Linderman. In that paper the composition of tubercles removed from mains in various sections of the country are shown to be much the same as natural bog iron ores.

FIG. 7

In one sense, a community is fortunate if it is so situated that it can secure its water by gravity and has no pumping expense. But it may be unfortunate in that its pressures cannot be raised to offset pipe capacity losses in order to afford fire protection. Then there are three alternatives—secure higher pressure with pumps or a new supply, lay larger mains, or restore reduced capacities.

There is a saving as a result of cleaning which is not reflected in the accounts of the water department where high insurance rates are exacted because of inadequate fire protection. The improvement in hydrant pressures and flows by distribution system cleaning often result in a lowering of insurance rates.

Most water works operators have seen water main cleaning work done or at least had it described to them so that a brief description

of the operation of cleaning may be superfluous but, for the benefit of those who are not familiar with this work, it is given herewith.

After the pipe is cut the machine is inserted and the pipe is permanently made up at the point of entry. The water is then turned on to the proper pressure and volume to give the machine the required rate of travel through the main. The machine emerges through a riser pipe at the end of the run. Best results are obtained when the machine travels at a velocity of about 50 feet per minute.

With 4-inch and 6-inch mains and also in the larger diameter pipes where water pressure machines cannot be used a heavy cable is passed through the main by means of a special carrier and light cable or rods. The machine is then attached to the cable and inserted into the line. Following this the pipe is made up, the water turned on to the proper amount for flushing and the machine pulled through the main by means of a windlass.

With either a cable-drawn or water-propelled machine a sufficient amount of water is allowed to pass the machine to carry away the dirt and incrustation which has been scraped from the pipe and ground up by the machine. The water carrying the sediment and cleanings is carried to the surface of the street through a riser pipe. Usually the water runs clear immediately after the machine emerges. After the machine is passed through the main the water is shut off, the risen pipe removed, the main reconnected and put in service. The entire operation requires only a few hours.

The following table may be of some help in determining how often pipe may be cleaned economically.

#1 PIPE DIAMETER	#2 AVERAGE COST PER FOOT	#3 5% INTEREST ON COST	#4 AVERAGE CLEANING COST PER FOOT	#5 CLEANING FREQUENCY
24″	$7.35	$.3675	$.28	1 year
20″	6.00	.30	.25	1 "
16″	4.36	.218	.24	1½ year
12″	3.18	.159	.22	1½ "
10″	2.65	.133	.22	2 years
8″	2.06	.103	.20	2 "
6″	1.61	.0805	.19	2½ years
4″	1.26	.0630	.18	3 years

The average per-foot cost of replacement was arrived at by taking valuation figures of appraisal in some 29 scattered plants, the valuations having been made by 11 different consulting engineers. This

cost per foot would be augmented, depending upon the kind of paving to be replaced. The interest in column 3 is figured at 5 per cent. Therefore, the time periods in column 5 would vary as those figures in columns 2 and 3 were changed to meet individual cases. In column 5 is shown the frequency with which pipe could be cleaned and still have the interest savings more than pay for the improvement.

There follows a tabulation of tests made in various plants throughout the country, showing pipe coefficients before and after water main cleaning and the resulting increase in capacities.

THE USE OF TREATED LUMBER IN WATER WORKS STRUCTURES

By Dan L. Lindsley

Before undertaking a detailed discussion of the various types of water works structures in which treated lumber or piling has been used, it might be well to consider some of the more general aspects of the subject such as the different treating methods which have been employed, the relative merits of each, the conditions existing which make treatment desirable, and wherein lie the economies of pressure treatment which have caused users to specify this process whenever treated timber was included in their construction programs.

When considering the merits of chemically preserved wood, the process of applying the preservative is fully as important as the toxicity of the preservative itself. The various methods of treatment include spraying, brushing, painting, dipping, soaking, and immersion in a closed retort under increased temperature and pressure. All but the last named are superficial in that little or no penetration of the preservative is secured. Dipping or soaking will accomplish better results than spraying, brushing, or painting, particularly if a hot and cold immersion is given. This latter is known as the open tank treatment and is used extensively in the butt treatment of poles. It is quite essential that timber treated in this manner should be well seasoned prior to treatment. Otherwise the preservative will not penetrate the wood. Authorities on the subject of wood preservation, such as those in charge of the section on wood preservation at the U. S. Forest Products Laboratory in Madison, Wisconsin, state that any of the non-pressure processes, particularly dipping, brushing, or spraying, are superficial in their results, are not to be relied upon for long life, and are not to be recommended when pressure treatments are available. Generally speaking, the superficial treatments, when used in the construction of buildings,

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A paper presented before the California Section meeting at Sacramento, October, 1937 by Dan L. Lindsley of the West Coast Wood Preserving Co. of Seattle, Washington.

reservoirs or other structures required in the water works field, will increase the life of the material from two to five years, provided the preservative itself is toxic to wood destroying organisms such as fungi and termites. Pressure treatment on the other hand, will increase the life from two to ten times. It might be well to add at this point that the materials are presumed to be exposed to decay or other destructive agencies, for under certain conditions wood will last indefinitely without treatment.

After accepting the fact that pressure treatment is the proper and economical method to use, there remains the question of what preservative to apply. There are a vast host of chemicals and chemical combinations which have, over the years, been proposed and used for the preservation of timber products. Many have come and gone because, for one reason or another, they did not meet the requirements of a satisfactory wood preservative. To be successful, a wood preservative must be toxic enough to kill fungi and insects; it must penetrate the wood to a sufficient depth and remain there over a period of many years; it must be available in large quantities, be of uniform composition, and be reasonably priced; and it must not damage the structural or physical qualities of the wood treated or the equipment used in applying it. Coal-tar creosote meets all of these various requirements and has established an unequalled record of effectiveness over a period exceeding one hundred years. Where wood is to be used in or on the ground, coal-tar creosote, applied by the pressure process, stands by itself as the best means of protection from both termites and decay.

For some purposes, coal-tar creosote has certain drawbacks which prevent its use. Its black oily nature prevents painting over it. In other cases its odor may be objectionable. Quite often the intended uses, wherein these characteristics would be objectionable, are just those where creosote protection is not so essential. They are frequently up off the ground, protected from open exposure, and in these locations, salts treatment is often sufficient. Such is the case in substructures of houses. In the City of Los Angeles, for instance, there exists an ordinance which requires that all wooden members below the first floor subfloor in wood frame construction be pressure treated for protection against dry rot and termites. Coal-tar creosote or chromated zinc chloride are the two preservatives specified for use in the treatment of these members. Wolman salts are permitted as an alternate. Chromated zinc chloride is a salts

treatment, applied under pressure the same way as creosote, but which leaves the lumber clean and dry. Practically all of the treated lumber now used in the Los Angeles area for house construction is treated by the salts process although for outdoor construction, such as bridges, bulkheads, docks, wharves, poles, etc., creosote continues to be used exclusively.

In water works structures creosote should be the sole choice for such uses as foundation piling, fences, bulkheads, trestles for supporting pipe lines, and similar outdoor construction. For reservoir roofs creosote has, to the best of my knowledge, been used exclusively in the past. Salts treatment might serve the purpose sufficiently well, provided it had been satisfactorily determined beforehand that the salts preservative proposed for use involved no human health hazard arising from condensation forming on the under side of the treated roof and dripping into the reservoir below. This question will be considered later when discussing treated timber in reservoir roof construction.

Among the uses made of pressure treated timber products in water works structures that of reservoir roofs constitutes by far the largest volume within the realm of my own experience. Another use which bulks large in the total volume is that of creosoted wood stave pipe lines for the transportation of water. This use is confined largely to the Pacific Coast states, chiefly the states of Washington and Oregon. In those states there are at least seventeen cities which transport part or all of their water supply through creosoted wood stave lines. The City of Seattle has some twenty miles of such lines ranging from 52 inches to 78 inches in diameter. The first of these was built about twenty years ago. At that time there arose considerable concern as to the deleterious effect which the creosote in the staves might have on the water, and in order to find the answer to this perplexing question a series of tests was undertaken in 1916 by the interested parties under the supervision of the Bureau of Industrial Research of the University of Washington. These tests were published by the University in 1917 under the title "Creosoted Wood Stave Pipe and Its Effect Upon Water for Domestic and Irrigation Uses." The findings of these tests were that thirteen days after an experimental creosoted pipe line had been in service, no taste of creosote could be detected in a sample of the water diluted with two parts of ordinary city water, and after twenty-nine days no taste could be detected in undiluted water flowing through it. The amount of creosote necessary in a given volume of water to

impart a creosote taste was also determined and from this was computed how much creosote would have to be continuously extracted from the staves of a creosoted pipe of given dimension to maintain a creosote taste in the water flowing through it. By then computing the total quantity of creosote used in the treatment of such a pipe line, it became evident that all of the creosote would be withdrawn from the staves in about a year and three months. This was known to be contrary to the facts as already determined from other uses of creosoted products and as subsequently proven in the extensive use of creosoted stave pipe lines. Such lines are now used by many cities with entire satisfaction and with no complaint of taste in the water except for the first week or two after the line is placed in operation. In addition to Seattle, some of the other cities operating creosoted pipe lines are Everett, Yakima, Port Townsend, and Aberdeen, Washington, Tillamook and The Dalles, Oregon, and Rawlins, Wyoming. The latter city has 40 miles of 14-inch line.

In southern California the largest use of treated timber in water works structures has been in reservoir roofs. In Los Angeles County the cities of Burbank, Glendale, Pasadena, Alhambra, Los Angeles, and Long Beach each have one or more reservoirs (with pressure creosoted Douglas fir roofs) ranging in capacity from 119,700 to 18,290,000 gallons. These roofs are flat, conical, single gabled, or multiple gabled. Most of them are made water tight by means of roofing paper laid over the wooden sheathing, though Los Angeles omits the roof covering as it constructs these roofs primarily to keep the sunlight from the water and thereby retard algal growths.

The conditions existing in the average reservoir roof are ideal for the development of decay. Situated as this roof lumber is, it is exposed to daily condensation of moisture on the under side while the upper side is well dried out by the hot sun. This provides optimum moisture conditions for decay within these wooden members. Furthermore, the large volume of water in a reservoir tends to hold the temperature within a narrow range and at a point favorable to the growth of wood destroying fungi. Unless the roof is well ventilated the circulation of air is retarded and this too encourages decay. Frequently proper ventilation is provided at the time of construction, only to be completely destroyed later by the planting and growth of shrubbery placed around the reservoir to hide it from public view. All in all, the wonder is that some of the untreated roofs have lasted as long as they have.

A few instances have come to my attention of very short service

life from untreated reservoir roofs, particularly where ventilation has not been given proper consideration. For example, the City of Beverly Hills replaced the roof on its LaCienega Avenue reservoir after 4½ years' service. The structural value of the untreated timbers had been completely destroyed by decay. This was a flat roof, close to the ground, the reservoir basin having been excavated and lined with concrete. Ventilating spaces, considered adequate at the time of construction, were placed around three sides and covered with wire screening. The screening was later covered with cheese cloth to keep out the hosts of small gnats that were getting through the screening and into the water. Shrubbery was planted around the structure to conceal it from view, and this, together with the cheese cloth, effectively cut off the air circulation and hastened the decay. The City of Burbank had a similar case a few years ago wherein a large part of an untreated roof was replaced with pressure creosoted lumber after less than seven years service. The decay in this roof was so far advanced that four or five of the 4 x 12-inch girders had completely decayed, broken in two, and fallen into the water. A screw driver could be punched through many of the 2 x 10-inch joists. In approaching the reservoir, the smell of decaying wood was very noticeable.

The cities enumerated above have adopted the use of pressure creosoted lumber to avoid these early failures. Although damage from termites has been relatively small as compared to that from decay, due, no doubt, to the location of the wooden members in these roof covers being up off the ground, there have been instances where termites, as well as decay, have contributed to the short service life. Creosote treatment eliminates the hazard from both these destructive agencies and guarantees a long and economical period of usefulness.

The largest users of creosoted materials in this country, namely the railroads, have found from experience extending over more than half a century that creosoted piling and lumber in bridge structures, where the material is in direct contact with the ground, will last at least forty years. As time passes and their experience records become more numerous, the average service life will undoubtedly prove to be even longer. A number of the railroads amortize their creosoted pile and timber trestles on the basis of a forty year life though there are, at the present time, a great many such structures which have already been in service more than forty years. The Lake Pontchartrain trestle in Louisiana is the oldest creosoted bridge in the United States, having been built in 1882–3, and it is still in daily use

after fifty-four years of service. In reservoir roofs, where the material is up off the ground and not subjected to mechanical wear, creosoted timber should last even longer than in the more severe exposure of bridge structures and a service life of fifty years does not seem at all beyond the realm of reasonable expectancy.

In order to show more clearly the dollars and cents saving possible from the use of creosoted lumber in reservoir roof construction, let us assume a typical case. Untreated Douglas fir of #1 Common grade in the sizes that would be required for such a job—4 x 12 girders, 2 x 10 rafters, and 1 x 6 sheathing for example—we will assume to cost $40.00 per thousand delivered at the jobsite. Cost of installation will be assumed at $20.00. This same bill of material, pressure creosoted by the 8# empty cell process, would cost about $55.00. The cost of each in structure would then be $60.00 and $75.00 per thousand respectively. The average service life of the untreated roof would be in the neighborhood of fifteen years. This life could, of course, be materially lengthened by repairs and replacements but for the purpose of this analysis an average life without major repairs should be considered. The life of the treated roof may be assumed at 45 years, as such a period of service can reasonably be anticipated from creosoted lumber in this type of construction. Cost of money we will assume at 5 per cent.

The prospective builder of the above reservoir, knowing the average life of his treated and untreated construction and the cost of each in place, can easily compute from an annual charge table the relative annual costs of the two. Using the above data he determines his annual cost on the untreated roof to be $5.76 per thousand as compared to $4.24 for a creosoted roof. This means an annual saving of $1.52 per thousand from the use of treated material. Although the first cost of the treated roof is 125 per cent of the untreated, the annual cost is but 74 per cent.

Being surprised at this revelation, the prospective builder studies his problem from a different angle. He wonders how much he could afford to pay for a treated roof without exceeding his annual cost of the untreated. Using his same data, he finds he could pay $102.00 per thousand instead of the $75.00 which he figured. Treated material proves better on this score. How long would the treated roof have to last, he asks, to give the same annual cost as the untreated? A little more figuring and he finds that it would have to last only 21½ years or but 6½ years longer than the untreated roof.

When the first creosoted roofs were built in southern California,

there was some concern felt from the possibility of condensation dropping from the treated material into the water and imparting a creosote taste thereto. In fact, the City of Burbank reported a few such complaints at the time their first creosoted reservoir roof was built in 1928. A coal tar product was used for sealing the joints in the concrete basin and this too might have been the cause of the complaints. However, they ceased shortly after the reservoir was placed in service and there have been none since. Pasadena had a similar case when their Allen Street Reservoir was placed in service. This reservoir has a creosoted timber roof frame covered with corrugated galvanized iron sheathing. In this instance, it was finally concluded that the coal-tar sealing compound was probably as much to blame as the treated lumber, but complaints were soon over and there have been none since. There are now four such treated roofs in service in Pasadena without complaint. None of the other cities listed have ever had any complaints.

When considering salts treatment for reservoir roof construction, the subject of condensation and drip should be given careful attention. The chemical composition of the salts preservative proposed should be known and studies made of the possibilities of these chemical constituents leaching from the wood and dripping into the water. These chemicals might present a health hazard if they were of themselves dangerous to human health and if they did leach out of the wood and into the water in amounts sufficient to produce a concentration that would be hazardous to the human system.

This subject has been given careful study in the past, chiefly in consideration of specific preservatives. Chromated zinc chloride, the salts treatment which I have mentioned above as being the one specified in the Los Angeles City building ordinance, was developed by the Grasselli Chemicals Department of E. I. DuPont de Nemours and Company. They have investigated quite thoroughly the possible hazard from the use of this preservative for treating lumber to be used in reservoir roof construction. They have exposed lumber, treated with chromated zinc chloride, to live steam and collected and analyzed the condensates to determine the leachability of both the zinc chloride and chromium compounds and to ascertain whether the concentrations obtained would impose health hazards. The condensates showed no chromium compounds whatever, indicating complete fixation of this ingredient in the wood. Only a very limited amount of zinc chloride was found, insufficient to be harmful to

human health. The conclusions reached by the Grasselli chemists and biologists were that lumber treated with chromated zinc chloride and used under conditions such as a reservoir roof will impose no health hazard nor render the water unfit for human consumption. When the facts are considered that the volume of water in a reservoir is large as compared to the area of treated lumber exposed to possible leaching; that this volume of water is constantly changing; that proper ventilation greatly reduces condensation; and that salts preservatives as now used in the wood preservation industry are compounded with the addition of mordant chromates which aid in fixing the preservative salts in the wood; the hazard from salts treated lumber in reservoir roof construction appears quite remote.

Before bringing this paper to a close, I would like to make some mention of the various types of reservoir basins and roofs now in use in southern California. In general, the reservoir itself is either a cylindrical steel tank or a concrete basin. The steel tanks usually stand above the ground although the city of Alhambra has lowered the two it has built so that they extend above the ground only ten or twelve feet. This permits concealing them more easily from the public view by planting of shrubbery and small trees. The concrete basins are frequently excavated pits lined with concrete. At some locations in the hills it has merely been necessary to clear the surface of the ground in a natural basin, remove the top soil and gunite the area. An earthen dike is usually required at these locations to close the lower end of the natural depression.

The customary practice in roofing reservoirs of the concrete basin type is to support the treated roof system on 8 x 8-inch redwood posts, spaced about 17 feet on centers. This is done to keep the creosoted lumber from direct contact with the water, though probably no trouble would result from the use of creosoted timber for this purpose. The small amount of treated material that would be in contact with the water as compared to its volume and its continual changing would not be sufficient to result in any complaints from taste—certainly not after the reservoir had been in use for a few weeks. When it is remembered that many of the cities in the northwest receive their water supplies through creosoted wood stave pipe lines, it is easy to realize that creosoted posts supporting a reservoir roof could have little effect in transmitting taste to the constantly changing volume of water passing through the reservoir.

On top of these 8 x 8-inch posts are placed 4 x 12-inch girders.

2 x 8 or 2 x 10-inch rafters on 16-inch centers are placed thereon, and a one-inch sheathing, either plain or tongue and grooved, covers these rafters. A composition roofing is then nailed to the sheathing. If a water tight roof is not desired, the composition roofing is omitted. Most of these concrete basin reservoirs have either flat roofs or flat pitched gables. Ventilation is ordinarily provided by a continuous screened opening around the eaves, supplemented by louvered penthouses along the ridge. This provides a good air circulation beneath the roof without permitting any dead air pockets in the corners.

SEASONAL TEMPERATURE VARIATIONS IN RELATION TO WATER TREATMENT

By Blair Burnson

The East Bay Municipal Utility District serves the cities of Oakland, Berkeley, Richmond, Alameda, Piedmont, San Leandro, El Cerrito, Albany, and Emeryville, together with a large amount of adjoining unincorporated territory in Alameda and Contra Costa Counties, all located on the east shore of the San Francisco Bay.

The District supplies the 500,000 residents of this East Bay area with surface water from five storage reservoirs. Four of the reservoirs, San Pablo, Upper San Leandro, Chabot, and Lafayette, are located within the immediate vicinity of the East Bay area, and collect the run-off from some 75 square miles of drainage area, and also act as terminal storage reservoirs for water from Pardee Reservoir. The fifth reservoir, Pardee, is located about 90 miles from the East Bay area and receives its entire supply of water from the Mokelumne River, which, at that point, has a drainage area of 575 square miles.

No water is delivered to the consumer without first having been treated at one of the five filter plants operated by the District. The District operates three rapid sand filter plants and two pressure filter plants. The rapid sand filter plants are: Orinda, with a nominal capacity of 28 m.g.d.; San Pablo, with a nominal capacity of 26 m.g.d.; and Upper San Leandro, with a nominal capacity of 21 m.g.d. The two pressure filter plants are: Chabot, with a nominal capacity of 5.5 m.g.d., and Grant Miller, with a capacity of 1.0 m.g.d. The Orinda plant is the newest of the District's plants and has been in operation only a little over two years. This plant has been described in detail by DeCosta (1). For the purpose of the discussion of temperature variations and water treatment, this paper will be limited primarily to a consideration of only two of these plants: San Pablo, with a nominal capacity of 26 m.g.d. and Upper San Leandro, with a nominal capacity of 21 m.g.d. These plants are

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supplied with water from San Pablo and Upper San Leandro reservoirs respectively.

San Pablo Reservoir has a total capacity of 15.6 billion gallons, a maximum depth of 220 feet at the dam, a contributing drainage area of 32 square miles, and a surface area of 850 acres when filled to capacity. The maximum depth of the reservoir at the outlet tower to San Pablo filter plant is 95 feet and by means of gates placed every 14 feet, water is drawn from the desired level and delivered by gravity through a tunnel 2.6 miles long to the aerator at the plant. The steps in the treatment process at the plant are: aeration, alum coagulation by gravity flow from the aerator through a baffled channel, sedimentation, filtration through rapid sand filters, chlorination, and lime treatment for pH control.

Upper San Leandro Reservoir has a total capacity of 13.4 billion gallons, a maximum depth of 215 feet at the dam, a contributing drainage area of 30 square miles, and a surface area of 788 acres when filled to capacity. The maximum depth of the reservoir at the outlet tower to the Upper San Leandro filter plant is 80 feet, and by means of gates placed every 14 feet water is drawn from the desired level and delivered by gravity through a tunnel 1.35 miles long to the aerator at the plant. The steps in the treatment process are: aeration, alum coagulation by mechanical mixing, sedimentation, lime treatment for pH control, filtration through rapid sand filters, and chlorination.

STORAGE RESERVOIRS AND SEASONAL TEMPERATURE VARIATIONS

In studying the effects of temperature variations upon water treatment, the first logical step is to study the effects of temperature changes upon the water in the storage reservoir. The quality of the water that is eventually to be handled at the filter plant is dependent upon the many factors at work in the storage reservoir. These factors may be classified under three headings: physical, chemical and biological; but in making this classification it must be kept in mind that the three are interrelated and mutually dependent, and that by changing one the other two will be influenced. The physical conditions include such factors as temperature, density, viscosity, transparency, turbidity, and the movement of the water; the chemical conditions include such factors as dissolved gases; and the biological conditions include such factors as seasonal distribution and behaviorism of plankton.

The specific heat of water is five times that of air, and for that

TABLE 1

San Pablo Reservoir and San Pablo Filter Plant—Summary of biological, chemical, bacteriological and physical data

Monthly averages for the four-year period July 1933–July 1937

DATA APPLYING TO THE RESERVOIR	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.
Temperature of the top water, degrees F	50	51	56	60	65	67	68	68	66	65	59	54
Temperature of the bottom water	50	50	52	55	58	60	62	63	62	61	58	54
Temperature of the air. Maximum daily	54	55	63	66	70	73	76	75	75	73	65	56
Temperature of the air. Minimum daily	39	41	44	46	50	53	53	53	52	50	44	40
Total number of copper sulfate treatments	1	0	1	0	2	2	5	2	2	0	0	0
Dissolved oxygen in % saturation, top	89	94	95	94	94	94	95	96	92	91	84	84
Dissolved oxygen in % saturation, bottom	85	82	81	75	66	54	51	45	42	51	60	80
Rainfall on watershed in inches	4.9	5.6	3.3	2.2	0.4	0.5	0.3	0.1	0.1	1.4	1.4	3.4
Transparency in feet	3	2	2	2	3	5	7	8	8	9	5	4
DATA APPLYING TO THE FILTER PLANT												
M.G.D. Treated	13	14	15	18	19	13	17	19	19	17	14	13
Temperature of water delivered to plant	50	51	51	54	58	62	63	65	65	63	58	54
Turbidity of water delivered to plant	21	23	33	32	20	17	13	6	6	5	7	7
Turbidity after coagulation and sedimentation	7	7	10	7	7	5	4	3	3	3	5	4
Alum dosage in grains per gallon	.91	1.3	1.4	1.7	1.9	1.5	1.3	1.0	.90	.83	.72	.72
Lime dosage in grains per gallon of quicklime	.23	.31	.34	.40	.42	.38	.37	.32	.30	.22	.23	.24
pH of water delivered to plant	7.4	7.4	7.3	7.3	7.3	7.3	7.3	7.4	7.4	7.4	7.3	7.3
pH of treated water leaving plant	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3
Per cent washwater used on filters	2.7	2.7	2.7	2.7	3.0	3.0	2.4	2.7	2.8	2.9	2.3	2.7
Chlorine dosage in parts per million	.36	.37	.40	.45	.33	.28	.22	.24	.27	.29	.31	.31
Bacterial tests of water delivered to plant—% of 10 cc. portions confirmed for coliform group	34	40	54	47	25	22	9	3	5	9	17	7

reason the temperature of the water will not vary as rapidly as the air with which it is in contact. (See tables 1 and 2.) The greatest variation in the temperature of the water naturally occurs at the surface since the lower layers are dependent upon conduction, con-

TABLE 2

Upper San Leandro Reservoir and Upper San Leandro Filter Plant—Summary of biological, chemical, bacteriological and physical data

Monthly averages for the four-year period July 1933–July 1937

DATA APPLYING TO THE RESERVOIR	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.
Temperature of the top water, degrees F	50	51	58	62	68	72	74	73	72	67	59	54
Temperature of the bottom water	50	50	53	56	57	60	61	62	62	61	58	54
Temperature of the air, maximum daily	53	55	63	65	71	74	79	79	79	75	66	56
Temperature of the air, minimum daily	34	37	40	42	46	49	50	51	47	45	36	34
Total number of copper sulfate treatments	0	0	2	2	2	2	4	0	1	1	0	0
Dissolved oxygen in % saturation, top	91	102	105	105	98	94	93	95	92	92	91	86
Dissolved oxygen in % saturation, bottom	82	90	85	71	50	35	24	20	16	23	74	80
Rainfall on watershed in inches	5.9	7.1	3.9	2.4	0.4	0.5	0.1	0.1	0.1	1.4	1.3	3.8
Transparency in feet	5	3	4	6	8	10	14	13	11	13	12	10
DATA APPLYING TO THE FILTER PLANT												
M.G.D. Treated	1.0	1.3	2.5	3.8	4.3	3.8	5.3	5.3	4.8	3.5	1.0	0.8
Temperature of water delivered to plant	52	52	53	57	59	59	63	64	63	62	59	55
Turbidity of water delivered to plant	15	22	20	16	12	11	9	8	7	6	6	7
Turbidity after coagulation and sedimentation	6	8	10	8	9	8	7	7	5	4	5	5
Alum dosage in grains per gallon	.92	.86	1.0	1.0	.83	.81	.77	.78	.79	.81	.93	1.0
Lime dosage in grains per gallon of hydrate lime	.43	.46	.53	.44	.42	.36	.42	.46	.45	.43	.60	.60
pH of water delivered to plant	7.6	7.7	7.7	7.7	7.6	7.6	7.6	7.6	7.7	7.6	7.5	7.6
pH of treated water leaving plant	8.2	8.2	8.2	8.0	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.2
Per cent of washwater used in back washing filters	1.2	2.1	1.7	1.9	2.2	2.2	1.5	1.6	1.7	1.8	2.0	2.2
Chlorine dosage in parts per million	.62	.56	.58	.60	.59	.51	.50	.51	.60	.64	.69	.71
Bacterial tests of water delivered to plant—% of 10 cc. portions confirmed for coliform group	28	23	25	24	12	14	10	6	12	12	2	8

vection, and radiation for changes in temperature. Water is a poor conductor of heat and also allows the passage of radiant heat only to a limited degree, so it may be assumed that these two factors have but little effect in conveying heat to lower water strata. However, the transmission of heat through water by convection is considerable, since this takes place whenever changes in temperature occur in a water stratum changing its density. Water attains its maximum density at 39.2 F. An increase in temperature or decrease in temperature from 39.2 F. will therefore decrease the density of the water. A standing body of water will therefore be stratified according to the temperature and density of the water.

The temperatures of the top and bottom waters of San Pablo and Upper San Leandro Reservoirs, taken in the vicinity of their respective outlet towers, show that at no time does the water in either reservoir reach the temperature of maximum density. Convection currents are almost continually at work in the upper strata of a reservoir due to the variations in night and day temperatures and variations in wind velocities. Since the upper strata are almost continuously in circulation it would be expected that the characteristics of the upper and lower water would be somewhat different. Tables 1 and 2 show that for these particular reservoirs the greatest differences in dissolved oxygen content occur in the months just prior to the fall overturn. When the top and bottom temperatures become identical these great differences no longer exist.

Viscosity is the transient resistance of a fluid to deformation; its internal friction. The viscosity of water varies greatly with changes in temperature, being approximately twice as great at 32 F. as at 77 F. Any particle of higher specific gravity than water, suspended in water, tends to sink. This tendency is opposed by the viscosity of the water. The viscosity of a water, therefore, affects the movements of plankton in the water. Hazen expressed the variations in viscosity of water due to temperature changes by the approximate formula:

$$V_t = V_{50} \frac{60}{t + 10}$$

where V_t is the viscosity at any natural water temperature,
V_{50} is the viscosity at 50 F., and
t is the water temperature in degrees F.

Most of the microscopic organisms or plankton, more particularly the chlorophyll-bearing organisms such as the algae and many of the protozoa, require light for growth and reproduction. They are therefore found in the upper strata of water. The transparency of the water profoundly influences the intensity of light at different depths and hence has a marked effect on the growth of plankton. The transparency is influenced by the turbidity of the water due to the presence of particles of matter in suspension, such as clay, silt, finely divided organic matter, and living and dead microscopic organisms themselves. In general, plankton growths thrive better at summer temperatures.

In order to determine the effect of temperature variations on the growth of plankton it is first necessary to investigate their food requirements. The kind and abundance of food are the most important controlling influences in the life of the plankton. The three main processes involved are photosynthesis, respiration, and bacterial decomposition. Most of the microscopic organisms that are of interest to water supply engineers belong to, or are closely related to the plant kingdom, and within their cells contain chlorophyll. Because of the presence of this substances they have the power of synthesizing their own food supply. Carbon dioxide and water are united to form formaldehyde, starch, and other carbohydrates. This process takes place only in the presence of light and is known as photosynthesis. Oxygen is liberated by the reaction.

Respiration is common to both plants and animals. Through this process oxygen is consumed and carbon dioxide given off. The process of photosynthesis requires light, but the process of respiration goes on either in the dark or in the light. Photosynthesis in lakes is therefore limited to the upper water strata, and the depth to which the process will take place in the upper strata will depend upon the transparency of the water. In the light, the production of oxygen due to the process of photosynthesis of chlorophyll-bearing plants is greatly in excess of the amount required for respiration. Likewise, the consumption of carbon dioxide in the process of photosynthesis is much greater than the production of carbon dioxide, due to respiration. Animal organisms such as the protozoa, rotifera and crustacea, and the fungi, contain no chlorophyll and do not have the photosynthetic power of food building, and hence must consume organic food that has already been prepared.

Bacteria in water live upon dead organic matter, taking in oxygen

and giving off carbon dioxide. If all of the dissolved oxygen is depleted the bacteria then derive oxygen from the organic food itself. The resulting decomposition gives rise to carbon dioxide and other gases, such as carbon monoxide and methane. This process is known as putrefaction. Because of thermal stratification, all of the oxygen in the lower layers of lakes may be used up by bacterial decomposition and considerable carbon dioxide produced.

The principal sources of dissolved oxygen in the water of lakes are the atmosphere and the process of photosynthesis. The principal sources of carbon dioxide are the decomposition of organic matter and the respiration of plants and animals. Only a small amount of carbon dioxide is absorbed from the atmosphere. The rate at which water will dissolve these gases from the atmosphere depends primarily upon the solubility of the gas, which is controlled by its partial pressure in the atmosphere; the solubility constant of the gas; the temperature of the water; and the amount of the gas already in the water. When water becomes warmer there is a tendency for gases to be driven from it due to lessened solubility. The solubility of oxygen in water when the water is exposed to an average atmosphere containing 20.9 per cent of oxygen at a pressure of 760 mm., including pressure of water vapor, varies from 14.62 parts per million at 32 F. to 7.63 parts per million at 86 F. The solubility of carbon dioxide in water in contact with air is about 1.4 parts per million at 32 F. and 0.6 parts per million at 86 F. It is well to remember, for example, that although a water may be 100 per cent saturated with oxygen at an average summer temperature of 64 F. it contains only about the same number of parts per million of oxygen as water 65 per cent saturated at 32 F.

In cases of heavy growths of algae the top water of a lake may become super-saturated with oxygen due to the process of photosynthesis; but the water does not long remain super-saturated due to the circulation of the water maintained by wind and convection currents, which bring the top water in contact with the air and with the under-saturated water in the lower strata. The decay of algae in a reservoir, following the exhaustion of the food supply or a copper sulfate treatment may reduce the amount of oxygen in the top layers faster than it can be absorbed from the air.

Under normal conditions of summer weather the vertical distribution of free carbon dioxide is usually the reverse of that of oxygen. It is usually high at the bottom because of bacterial activity,

and low at the surface because the partial pressure of the gas in the atmosphere is low, and because the photosynthetic activity of algae is greatest at that point. Due to the growth of plankton, the entire amount of free carbon dioxide may be used up. In the absence of free carbon dioxide the plankton may utilize the half-bound carbon dioxide of the dissolved bicarbonates, chiefly those of magnesium and calcium. When the free carbon dioxide has been exhausted the water reaches a pH of about 8.3 or higher. This has occurred on several occasions in two of the District's reservoirs, Lafayette Reservoir, storing about .85 billion gallons, and Chabot Reservoir, storing about 3.5 billion gallons. On these occasions the pH of the top water started to increase in the months of February, March, or April. pH values as high as 9.0 have been noted, and the average pH value has been as high as 8.6 for a period of six and seven months. Recent tests made on Chabot Reservoir gave the following pH values at different depths in the reservoir:

Depth, in feet	*pH*
Top	8.7
15	8.5
30 (bottom)	7.4

Unless the reservoir contains a very soft water there will be a definite tendency for the water in the upper strata to precipitate out $CaCO_3$ during the periods of high pH. During the summer months, therefore, the water in the upper strata may be softer than that in the lower strata.

At the period of overturn the amount of oxygen and carbon dioxide, the pH, the hardness, etc. will be the same throughout the entire body of water. It will be noted that there is only one period of overturn that occurs in San Pablo and Upper San Leandro reservoirs. The overturn starts usually in the later part of October and continues into February. In colder climates there are usually two periods of overturn, one in the spring and one in the fall.

The microscopic organisms found in water are of interest primarily because of the tastes and odors imparted to the water by their growth and decay. The District has found from past experience that the four organisms which are most apt to produce tastes and odors are: Aphanizomenon, Anabaena, Ceratium, and Volvox. Aphanizomenon may occur during any month of the year, Ceratium occurs usually during the months from March to October, Anabaena from April to December, and Volvox from March to December. Copper sulfate

is used to control these organisms and other organisms, such as diatoms, which may increase to the point of abnormally shortening filter runs. The usual dosage varies from 3 to 4 pounds per million gallons of water in the upper ten feet of the reservoir. Moore and Kellerman (2) state that the amount of copper sulfate required increases or decreases about 2.5 per cent for each degree C. change in temperature below or above 15 C. In other words, if the water is colder more copper sulfate is required to do the same work; if warmer, less. For reservoirs that vary as little in temperature as San Pablo and Upper San Leandro reservoirs an attempted temperature correction of this kind does not appear to be justified. There are so many variables involved in the treatment of a reservoir with copper sulfate that it seems a folly to attempt to draw a fine line between the correct dosage and the incorrect dosage. Practical methods for applying copper sulfate, even at their best, do not insure uniform distribution of the copper; the exact volume of a reservoir is difficult to determine; the effect of wave and wind action evades exact determination as does the effect of the chemical characteristics of the water; and the resistance of the organisms themselves is difficult to predict. Experience may show that within limits certain groups of organisms respond to lower dosages than others. It appears to be practical, therefore, to select a fixed dosage for each group based upon past experience, plus an added "factor of safety" to take care of variables throughout the year. Under dosage, besides being a waste of copper sulfate, fails to destroy the organisms and fails to prevent tastes and odors in the water due to the continued growth of these organisms. This added "factor of safety" seems to be a justified insurance against the occurrence of tastes and odors at any season.

Tables 1 and 2 contain a summary of some of the biological, chemical, bacteriological and physical data relating to San Pablo and Upper San Leandro reservoirs. The top and bottom water temperatures, the top and bottom dissolved oxygen content and the transparency of the water were determined twice weekly in the vicinity of the outlet tower of each reservoir. The total number of copper sulfate treatments made during each month of the four year period is shown in the tables. As would be expected from the foregoing discussion the greatest number of copper sulfate treatments were made during the summer months when the temperature of the water was the highest, and the transparency was the greatest.

Although it may be assumed that an abundance of carbon dioxide would be supplied by the bottom water to the top water during the period of overturn, apparently the lower temperatures counteracted the effect of an increased food supply. It will also be noted that the transparency begins to decrease during this period due to rainfall and surface runoff. The variations in dissolved oxygen during the year show definitely the results of thermal stratification of the water in the reservoirs.

An increase in the bacterial content of a reservoir usually occurs as a result of rains. The immediate result of a smart shower is to increase the contamination by introducing fresh water from the surface of the ground. It will be seen in tables 1 and 2 that the presence of bacteria of the coliform group increased in both reservoirs during the periods of greatest rainfall. The forces tending to bacterial self-purification in a reservoir are: sedimentation, the activity of other micro-organisms, light, temperature, and food supply. The subsidence of bacteria, either by virtue of their own specific gravity, or as a result of their attachment to larger particles of suspended matter is without doubt partly responsible for the changes in the number of bacteria in the upper layers of water at rest. When bacteria are in a medium in which they are able to grow and multiply, warmth, within reasonable limits, will favor their development. For most intestinal bacteria the conditions necessary for growth and multiplication are not realized in water and the higher the temperature the more rapidly the bacteria die off (3). Sunlight has some germicidal effect due to its ultra-violet rays. The clearer the water the more effect this would have upon the bacteria. From tables 1 and 2 it will be seen that the bacteria started to decrease in the months of May and June immediately following the sharp decrease in rainfall. The reason for this decrease was probably due to four factors: The settling out of suspended particles and bacteria themselves (note decrease in turbidity of water being delivered to filter plants); an increase in water temperature; an increase in the transparency of the water increasing the penetrating power of the sunlight; and the increased activity of microscopic organisms such as the protozoa and rotifera.

THE EFFECT OF SEASONAL TEMPERATURE VARIATIONS UPON FILTER PLANT OPERATION

It has been shown that the quality of the water in a reservoir will vary with seasonal temperature changes and that at any one season

the quality may vary at different depths. Some of the advantages of being able to draw water from any depth in a reservoir are:

1. Water containing microscopic organisms can be avoided.
2. Water of warmer temperature can be avoided.
3. Water containing the greatest turbidity can be eliminated.
4. The content of dissolved oxygen and carbon dioxide can be controlled within limits.
5. Water from the deeper depths may contain iron, manganese, or color, and can be avoided.
6. Odors of decomposing organic matter can usually be eliminated by drawing from shallower depths.
7. Water of the correct pH for coagulation may be selected.

AERATION

The main points to be kept in mind when studying the effect of temperature variations on the aeration process are:

1. The amount of gas that can be dissolved in a cold water is greater than the amount that can be dissolved in a warm water. It has already been shown how the amount of dissolved oxygen and carbon dioxide required to produce saturation varies with the temperature of the water.
2. The higher the water temperature, the more rapid will be the rate of gas escape from the water in cases of over-saturation and, likewise, the higher the temperature, the shorter will be the time required for a water to become saturated with a gas in cases of under-saturation.

COAGULATION AND SEDIMENTATION

The effect of temperature variations upon the coagulation of water with aluminum sulfate is open to much discussion. Ellms (4) states that in climates where the temperature of the water drops nearly to the freezing point the coagulation of suspended matter is imperfectly accomplished. He states,

> "The diminished efficiency appears to arise from some modification of the gelatinous properties of the chemical colloids produced, and which may be the result of a retardation of the chemical reactions involved, and the formation of smaller flocs having a diminished absorptive power."

Ellms gives a series of diagrams by Streeter which show that for the one particular water on which these observations were made, the alum dosage required at the higher temperatures were consider-

ably lower than those required for the same degree of turbidity in a cooler water.

Daily records of turbidity and temperature and alum dosages taken over a period of four years at Decatur, Illinois (5), indicated that for turbidities of 50 parts per million the required alum dosages at 32–41 F. was about 25 per cent higher than for temperatures of 77 to 86 F. For turbidities of 200–400 parts per million the alum dosage was 100 per cent higher at the lower temperatures.

Another observer (6) reports that,

> "In winter filter plant operation there are certain changes coincident with low water temperatures. It is evident that winter floc differs from that prevailing with warmer water. It is smaller and more compact per unit of coagulant fed per unit of turbidity. Generally speaking, more care and attention is required in the feeding of coagulants during the colder months."

Willcomb states that, (7)

> "Generally speaking, the lower the temperature of the water the more retarded the chemical reaction and consequent floc formation. Due to the increased viscosity of the water and changed surface tension of the flocs themselves, the particles resist coalescing tendencies and consequently require more prolonged agitation to increase the size of the flocs such that they will settle out."

On the other hand, another set of experiments (8) made, using alum for color removal, indicated that an increase in the amount of coagulant was necessary at the higher summer temperatures and that at the lower temperatures the amount of coagulant to produce the same degree of color removal was less. Floc formed decidedly faster at lower temperatures. At summer temperatures the amount of coagulant required was from 1.6 to 2.2 times as high as the required dosage at winter temperatures. A series of tests made by Leipold (9) on waters ranging in temperatures from 36 to 75 F. showed that there was no preventive or retarding effect on alum floc formation with low raw water temperatures.

A study of the temperatures, turbidities, and alum dosages over a period of four years at San Pablo and Upper San Leandro filter plants does not reveal much of value as far as the effect of temperature changes upon coagulation is concerned. The maximum variation in the four year average monthly temperatures was only 12–15

degrees F. A study of the daily temperature records for each day of this four year period shows that the highest temperature recorded at San Pablo plant was 67 F. and the lowest 50 F. At Upper San Leandro Plant the highest was 70 and the lowest 49 F. The turbidities of the water reaching the filter plants were low for the four years period, and the alum dosages were correspondingly low. Higher alum dosages were required during the periods of high turbidity which in all cases occurred during the colder months of the year. The turbidity occurring during the colder months was due to rainfall runoff and consisted almost entirely of silt and clay. The turbidity occurring during the warmer months was due almost entirely to living and dead microscopic organisms. It has been observed that the floc formed during the colder months is smaller than that formed during the warmer months; and that the optimum dosage for coagulation in the colder months occurs within a very narrow range.

It is generally conceded that the temperature of the water affects the rate of sedimentation. A decrease in temperature increases the density and viscosity of the water and suspended matter settles more slowly. It is increased viscosity more than increased density which is involved. An interesting effect of temperature differences between the water already in a sedimentation basin and the water entering the basin was noted at Ottawa (10). On days when the incoming water was colder than the water already in the basins better settling took place and very little floc was delivered to the filters. On days when the incoming water was warmer it tended to flow along the surface of the basin and considerable floc was delivered to the filters.

FILTRATION

The more apparent effects of seasonal temperature variations upon rapid sand filter operation are:

1. Loss of head varies with changes in water temperature.
2. Required washwater rates vary with temperature variations.
3. The kind and the amount of material delivered to and existing in a filter varies with seasonal temperatures.

The temperature of the water affects its viscosity and the more viscous the water, the more frictional resistance it offers to passage through the sand bed. Hazen (11) developed a formula for calculating the loss of head in a slow sand filter based upon the rate of flow of water through the sand, the size and depth and cleanliness of

the sand, the head of water, and the temperature of the water. Solving this formula shows that the loss of head at 32 F. is 2.0 times as great as the loss of head at 74 F., other factors remaining the same; or for a given head on a filter twice as much water will pass through the sand in a given time at 74 F. as compared to the amount at 32 F. Hulbert and Feben (12) developed from a series of tests on rapid sand filter sand a formula for the loss of head in a clean filter using: depth of sand, size of sand, rate of flow through sand, porosity of sand, and temperature of water. According to their formula, the loss of head at 32 F. will be about 1.8 times the loss of head at 74 F. They found that the loss of head as calculated by the Hazen formula was decidedly higher than the actual losses determined by their experiments. Fair and Hatch (13) state that the loss of head is about twice as great at 32 F. as 68 F.

Hulbert and Herring (14) developed a formula for calculating the rate of application of washwater for any desired sand expansion using, besides these two factors, the size of sand and the water temperature. A solution of their formula shows that in order to maintain the same sand expansion of 50 per cent the rate of application of washwater in inches per minute at 32 F. will have to be increased 50 or 60 per cent for a temperature of 70 F. The higher rate at the higher temperatures is, of course, due to the decreased viscosity of the water. Hazen developed a formula for the rate of washing filters based on the effective size of the sand, the temperature of the water, and the sand expansion. The application of this formula shows that for the temperature range of 32 to 70 F. the rate of washwater at the higher temperature will have to be about 60 per cent higher in order to obtain the same sand expansion at both temperatures. Lawrence (15) found that this formula checked closely with his experimental data at the Baldwin filter plant. It was found that a 50 per cent sand expansion could be obtained throughout the year by increasing the rate of wash 4 inches per minute for each 10 degrees F. rise in water temperature. The rate of wash varied from 24 inches at 32 F. to a maximum of 38–39 inches at 72 F. and over. It is seen from this discussion of filter washing that it is important that the rate of filter wash be varied during the season in order to provide sufficient washing action at all seasons to prevent sand losses, particularly during the colder months.

It is usually conceded that sand filters are more efficient during the warmer months than during the colder months. The explana-

tion given for this is that during the warmer months, when the temperature of natural surface water is the highest, the microscopic plant and animal life are most abundant; and the quantity of organic colloidal matter brought to the filters is therefore greater. Where clay turbidity occurs during the warmer months this additional colloidal organic matter may reduce the amount of coagulant otherwise needed; but on the other hand, the presence of these natural organic colloids, when the water is quite free from other suspended matter, merely helps to clog the filter beds and to increase the required amount of wash water. This, in part, accounts for the fact that the percent of washwater required at San Pablo and Upper San Leandro plants is as high during periods of low clay turbidity as during periods of high clay turbidity.

CHLORINATION

The disinfecting action of chlorine proceeds at a slower rate with the lower water temperatures. To disinfect a cold water in the same period of time as a warm water will, therefore, require higher chlorine dosages. Chlorine residuals persist longer in a cold water than in a warm water. Many observers have reported that lower chlorine residuals are detected by consumers during the winter months and that for this reason it is necessary to reduce chlorine residuals as the water grows colder. The explanation for this phenomenon is probably found in the fact that at the lower water temperatures the chlorine residual was actually much higher than was indicated by the orthotolidine test. Prior to the publication of the seventh edition of "Standard Methods for the Examination of Water and Sewage," in 1933, the effect of low water temperatures on the chlorine test using ortho-tolidine was not generally taken into account.

An interesting set of experiments was conducted by Heathman, Pierce and Kabler (16) on the resistance of various strains of *E. typhosa* and members of the coliform group to chlorine and chloramine. They demonstrated that the time required for chloramine, and in some instances chlorine, to kill strains of *E. typhosa* and members of the coliform group is appreciably greater at low temperature than at room temperature. They also showed that it is possible for viable *E. typhosa* to persist in waters treated with chlorine or chloramine as long as, and in some instances longer than, members of the coliform group.

The chlorine demand of a warm water is greater than that of a

cold water due partly to the greater quantities of oxidizable organic matter usually present in the former and partly to the increased activity of the chlorine at higher temperatures. Tables 1 and 2 show the average monthly chlorine dosages applied at two of the District's filter plants for a four years period. As noted before, the temperature variations were small and in general the chlorine dosage was increased with increased raw water pollution. One hundred percent removal of bacteria of the coliform group was accomplished at all times.

LIME TREATMENT FOR pH CONTROL

The purpose of lime treatment is to prevent corrosion of pipe lines by building up and maintaining a protective coating on the pipe. In most waters calcium carbonate is the salt which is most useful in forming this protective coating. It is generally accepted that warm water has a greater tendency to corrode pipe or to build up coatings on pipe. Calcium carbonate becomes less soluble as temperature increases, and therefore the required concentration of this salt to produce a protective coating will vary with the water temperature, and will be less for a warmer water. For reactions of this kind involving a solid and a liquid, an increase in temperature of 18 F. about doubles the speed of reaction in either direction. Langelier (17) has developed a formula for determining the pH_s at which a given water is in equilibrium with solid calcium carbonate; or in other words, the pH at which a water will have a tendency to neither lay down a protective coating of calcium carbonate or to dissolve an existing coating. A solution of this formula shows that for a change in temperature from 77 F. to 32 F. the pH_s would have to be increased 0.26 pH units in order to maintain the calcium carbonate equilibrium. The warmer the water the lower the required pH_s. Tables 1 and 2 show that the pH of the raw and treated District waters varies but little. As far as corrosion is concerned the temperature and chemical variations of the water are negligible. It will be seen that the variation in lime dosages is due primarily to variations in alum dosages.

SEASONAL TEMPERATURE VARIATIONS IN OTHER CALIFORNIA WATER SUPPLIES

Temperature data applying to the water entering the distribution systems, received from seventeen cities in California, indicated that

the maximum monthly temperature variation for any one surface supply was 37 degrees F. The maximum monthly average for this supply was 77 F. and the minimum 40 F. Cities using deep wells as their source of water supply reported average temperatures of 60 F. to 75 F. One case is reported of an artesian well in Southern California delivering a water of 110 F. This water is cooled in coils, by evaporation by means of passing a thin film of water over the coils, to a temperature of 80 F. before delivering it to the system.

The question arises—how high can the temperature of water be and still be palatable to the average consumer? Turneaure and Russell (11) state that a water having a temperature of 50 F. is usually satisfactory to the consumer where temperatures of 60 F. or above are objectionable. About thirty years ago Whipple (18) derived a formula showing the relationship between the temperature of a water and the percent of objecting consumers:

$$p = \frac{(d - 45)^2}{9}$$

where p is the percent of objecting consumers, and
d is the temperature of the water in degrees F.

A solution of this formula shows that for a water temperature of 45 degrees none of the consumers would complain; at a temperature of 65 F. about half of the consumers would object; and for a water temperature of 75 F. all of the consumers would object. The temperature of the water entering the distribution system will vary throughout the system depending upon the depth of burial of the pipe lines, the type of storage tanks and reservoirs, the season of the year, etc. Seasonal temperature surveys of distribution systems throughout the state would undoubtedly provide some interesting data on these subjects.

SUMMARY AND CONCLUSIONS

1. Seasonal temperature variations influence to a varying degree the characteristics of a surface water and the processes by which this water is treated.

2. The temperature variations occurring in the waters of San Pablo and Upper San Leandro reservoirs have an effect upon the biological and bacteriological life in the reservoir, and upon the chemical and physical characteristics of the water; but so many variables are concerned that it is difficult to ascertain the exact

degree to which temperature is responsible for the changes which occur.

3. The water entering the San Pablo and Upper San Leandro filter plants varies but little in temperature during the year and the direct effect of the temperature factor itself upon the various treatment processes within the plants is slight.

4. The District maintains a careful check of the effect of seasonal variations upon the water in the reservoirs and the treatment processes at the filtration plants:

(A) Reservoir Observations:

a. Atmospheric temperatures, wind velocities, evaporation and rainfall, recorded daily.

b. Top and bottom water temperatures, top and bottom dissolved oxygen, plankton catches, and transparency, recorded twice each week.

(B) Filter Plant Observations:

a. Water temperature, recorded daily.

b. Laboratory coagulation test, made daily.

c. pH of raw water, turbidity of raw water, recorded daily.

d. pH of treated water, recorded every two hours.

e. Chlorine residual, recorded hourly.

f. Turbidity of filtered water, checked hourly.

g. Bacterial tests of raw and treated water, made daily.

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COAL VERSUS SAND AS A FILTER MEDIUM

By O. J. Ripple

Considerable interest has been shown in anthracite coal, or anthrafilt as it is now known, as a filter medium, and articles relating to this material appear quite frequently in the various publications relating to the water works field. Many claims have been made that it is a better filter medium than sand. Denver has several filter plants, some of which use sand and some anthrafilt. This fact might seem to indicate that a direct comparison could be made between the two filter materials from our operations, however this is not readily done for the reason that the plant having sand for a filter material and using the same quality of water, as is used in the plant having anthrafilt for a filter material, is a much older plant and has not the same operating facilities as the newer plant. Therefore direct comparisons of plant scale operations are hard to make.

The five filter plants now in operation for Denver, are scattered at intervals over a 26 mile line and use several sources of supply, differing widely in character. This paper will be based on the experimental work which has been conducted at our North Side Filter Plant and on material contained in published articles. I am going to repeat some of the advantages which I believe that anthrafilt has over sand as a filter material, with the idea that repetition may wear down some of the resistance to the acceptance of anthrafilt as a filter material, first used over 40 years ago by Mr. James H. Fuertes at Steelton, Pa. That plant is still in operation and although there are about 40 water purification plants in the United States now using anthrafilt in part or all of their filters, as compared to many times that number using sand, it is my opinion that this material has been more slowly accepted than its merits warrant.

Anthrafilt is approximately half as hard as sand; when dry it weighs about 53 pounds per cubic foot and dry sand weighs about 100 pounds

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A paper presented at the meeting of the Rocky Mountain section at Santa Fe, September, 1937 by Oliver J. Ripple, Superintendent of Filtration, Board of Water Commissioners, Denver, Colo.

per cubic foot. Since a ton of sand is equivalent to about 0.75 of a cubic yard and a ton of anthrafilt is equivalent to about 1.4 cubic yards many plants may find anthrafilt cheaper than sand, especially when the other factors in favor of anthrafilt are taken into consideration. Anthrafilt, being lighter than sand, requires about half as much backwash velocity as sand of the same size to obtain a 50 per cent expansion in beds of the same depth. This lower rate of wash makes possible a saving in first cost in the equipment necessary for washing the filters and a farther saving is possible in the reduced depth and size of the supporting gravel or anthrafilt bed. This lighter material does not pack in the filters as much as the heavier sand, its resultant specific gravity in water being about one-third that of sand, and, due to a difference in the shape of grains, it has a larger percent of voids than a sand bed of the same size grains, therefore higher rates of filtration have been used than have been considered practical with sand. This also makes it possible to lower the first cost as anthrafilt filters can be designed with less area than sand filters for the same quantity of water, when the same percents of material passing a given set of screens are used in both units. The percent of wash water is also lowered and the filter runs lengthened in most anthrafilt installations where sand has previously been used.

The available data on attrition loss shows it to be low, about 0.2 percent per year, or about the same as for sand, when used in water which does not coat the sand. The attrition loss seems to be independent of the specific gravity, as the heavier, harder sand has more momentum in the collisions during washes and its attribition loss is about the same by percent of volume as with the lighter, softer anthrafilt.

Anthrafilt is not soluble in acids or alkalies and does not coat to any harmful extent in our Denver filters; sand is soluble to some extent in alkaline waters and coats with some waters containing lime, manganese and iron.

Some operators have found an increased removal of turbidity and bacteria using anthrafilt, others have not noted any difference, but I do not know of any operator, who has found that sand of the same size and depth as anthrafilt, gave better results under comparable operating conditions.

For the sake of comparison we have run some experiments using sand and anthrafilt in small glass filters to see if the floc would pene-

trate deeper in one material than in the other. We used the same sieves to grade the two materials and found that the floc did penetrate deeper into the anthrafilt than into the sand and that the runs were somewhat longer with about the same loss of head as shown in table 1.

However it will be noted that the average size of the anthrafilt was larger than the average size of the sand for the same sieves. It has been our experience that the coal passing a given sieve is approximately 8 percent larger in size than sand passing the same sieve, for sieves of 10 to 14 mesh and about 13 percent larger for 20 to 65 mesh sieves. We, therefore, have two separation sizes for

TABLE 1

FILTER NO.	DEPTH, INCHES		SIEVES		AVERAGE SIZE, MM.		RATE OF FILTRATION, MG. PER ACRE PER DAY	AVERAGE LENGTH RUNS, HOURS	AVERAGE HEAD LOSS, FEET	AVERAGE TURBIDITY			CRITICAL DEPTH, INCHES PENETRATION	
	Sand	Anthrafilt	No.	Size, mm.	Sand	Anthrafilt				Raw	Coagulated	Effluent	Average	Maximum
1	22		35–48	.417–.295	.356		170	8.00	4.76	5.2	5.9	1.02	5.66	6.00
2		22	35–48	.472–.385		.428	170	8.15	4.70	5.2	5.9	0.88	6.33	7.50
3	27		28–35	.589–.417	.503		170	9.70	4.93	5.2	5.9	0.99	8.00	10.00
4		27	28–35	.652–.472		.562	170	11.97	4.98	5.2	5.9	0.93	8.66	10.00
5	32		20–28	.833–.589	.711		170	14.70	5.00	5.2	5.9	1.05	10.90	12.00
6		32	20–28	.943–.652		.797	170	18.70	5.15	5.2	5.9	1.05	13.00	15.00
7	40		14–20	1.170–.833	1.001		170	20.82	6.15	5.2	5.9	1.13	15.75	21.00
8		40	14–20	1.267–.943		1.105	170	34.25	6.05	5.2	5.9	1.03	23.35	28.00

our sieves, one for sand and one for anthrafilt the sizes being given in table 1.

The head loss in our North Side Filter Plant is limited to 4 ft. in the large filters; to about 5 ft. on experimental filters No. 1 to 6; and to 6 or 7 ft. in the experimental filters No. 7 and 8. The rate of filtration used for both sand and anthrafilt was 170 m.g. per acre per day.

Coagulation was poor due to a high rate thru the large plant which overloaded the coagulation basin. Some of the runs were short because of micro-organisms.

The average chemical dosage during the runs was alum, .771 grains per gallon; quick lime, .258 grains per gallon; and sodium aluminate,

.095 grains per gallon for raw water having a turbidity of 5.2 p.p.m. The average effluent turbidity was about 1 p.p.m. and was due to poor coagulation.

The following are average characteristics of the water; temperature, 21.0° C.; micro-organisms, 695 standard units per c.c.; pH raw water, 7.97; effluent 7.78; methyl orange alkalinity, raw water, 71 p.p.m., effluent, 69 p.p.m.; phenol alkalinity, 0 p.p.m., soap hardness 90 p.p.m.

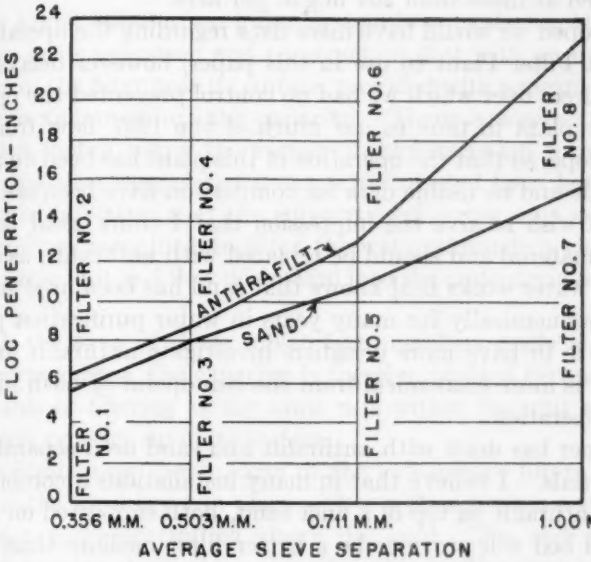


FIGURE. 1 AVERAGE DEPTH PENETRATION OF FLOC FOR ANTHRAFILT AND SAND FOR MATERIAL PASSING THE SAME SIZE SIEVES.

Figure 1 is included to show the greater average penetration of the floc into the anthrafilt than in the sand passing the same size sieve.

The maximum penetration of floc in the experiments covered in table 1 was 21 inches for the coarse sand and 28 inches for the coarse anthrafilt, these coarse layers are, naturally, deeper than would be used in the ordinary filter for water purification. It is my opinion that a bed of 24 inches to 30 inches of anthrafilt graded to fit the character of the water to be filtered should be all that is necessary even tho the practical rate of filtration is higher than has ordinarily

been used for sand. The average depth of sand beds has been about 30 inches and our new Moffat Filter Plant for Denver has 22 inches of sand (effective size about .50 m.m. and uniformity coefficient about 1.50) and was designed to filter at 125 m.g.d. per acre and it is is expected that the rate can be increased to 175 m.g.d. per acre.

The anthrafilt in our North Side Filter Plant is 48 inches deep and has an effective size of .60 mm. and a uniformity coefficient of about 1.85. It was designed to run at the rate of 170 m.g.d. per acre and has operated at more than 204 m.g.d. per acre.

It was hoped we would have more data regarding the operation of the Moffat Filter Plant to use in this paper, however delays from various sources over which we had no control prevented the opening of the new plant in time to use much of the 1937 flow from the Western Slope, so that the operation of this plant has been on a very limited scale and no usable data for comparison have been obtained.

I do not wish to give the impression that I think sand is passé as a filter material and should be replaced with anthrafilt, as everyone in the water works field knows that sand has been used successfully and economically for many years in water purification plants. My desire is to have more designers investigate anthrafilt and use it where it is more economical from the standpoint of both installation and operation.

This paper has dealt with anthrafilt and sand used separately as filter materials. I believe that in many installations a combination of coarse anthrafilt on top of a finer sand, both supported on a suitable gravel bed will prove to be a better filter medium than either used alone.

DEVELOPMENTS OF RAPID SAND FILTRATION TO INCREASE CAPACITY

By Ira H. Jewell

The Jewell Sub-Surface Filter System is a regular rapid sand type of filter in its operation and construction, but with an intermediate section of the filter near its surface, provided with a means to increase the area and therefore the capacity. There is a series of pockets placed 6 inches below the surface in checkerboard formation into which the inlet coagulated water is distributed by a header. This header is valved so that the sub-surface filtering area can function separately or combined to filter the water through a clean section of the same unit and flow downward into the underdrain or collecting system.

With the area of these sub-surface members made equal to the filter surface area, the capacity is thereby doubled because the area is capable of filtering at the same rate within the unit as the conventional practice upon its surface.

The illustration shows some of the sub-surface filters suspended without the sand layer in place with a section broken away and the extension pipes protruding above the sand. The end view of the general drawing shows the action of washing with the sand expanded and rising to the height of the slotted pipes. When the washing is completed the filtering layer settles down to its normal level and the filter appearance is the same throughout its surface.

The depth into the filter which these sub-surface filters are placed is 14 inches and this leaves a distance of 6 inches between the sand surface and contact of the top of the sub-surface filter with the sand for the sub-surface filtering.

A paper presented before the New York Section meeting at Jamestown, March, 1938. The author, Ira H. Jewell, Water Purification Engineer of Chicago, Illinois was associated with the Lousville, Ky. filtration experiments conducted by Geo. W. Fuller in 1895.

JEWELL SUB-SURFACE FILTER EQUIPMENT. GENERAL PLAN AND DETAIL OF INDIVIDUAL UNIT

WASHING ACTION

When washing is required it is only necessary to close the inlet valve and open the wash valve which is attached to the same supply header connected to the sub-surface filters. This wash is both from the reverse flow below the bed as usual (in about half the volume of high velocity practice) and also from the sub-surface filters. A triple effect is produced, namely, (1) reverse from below, (2) the sub-surface members and (3) the attached pipe with slots which protrudes upward from the bed about 6 inches and extends into the expanded portion of the sand. The illustration at right shows the action of the water flowing into the filter for the washing. This wash will scour and agitate the unit without the wide expansion of high velocity practice and the sand is therefore kept more compact. This serves to scour the sand grains, causing them to rub against each other for better cleaning than when widely separated when all of the water is applied below. This expansion with triple effect washing is only 20 per cent while with high velocity practice with equivalent volume it would otherwise be 50 per cent to 60 per cent.

GENERAL LAYOUT OF PLANT

A complete filter is shown with a multiple of these sub-surface filters attached to the supply header to reach crosswise of the filter walls and spaced 12 inches apart, and then these rows are duplicated with the same 12 inch spacing. They have the appearance of checkerboard formation with a multiple of them equal to the filtering surface. This is the reason the capacity of the filter is doubled or has an increase of 100 per cent because the sand area below the surface from which separate filtering takes effect is equal to building the filter area twice its original size. This applies to units of any given size.

The volume of wash water preferably employed is 1 foot vertical rise from reverse flow and 2 feet vertical rise from the sub-surface filters, making a total of 36 inches to rise and spill into the wash troughs for drain. The wash is quickly and effectively accomplished and keeps the filter free of mud balls, capable of continued good operation. The action of this wash water in triple effect constitutes intrinsically the equivalent of the mechanical rake which was formerly used with the old Jewell tub-type filter that was in practical operation for many years.

OPERATION

When the modern filter is provided with coagulating and settling to the extent of a good floc formation and removal of excessive turbidity and micro-organisms so the water flowing to the filter contains approximately 5 to 20 p.p.m. suspended material, there is not the penetration of impurities deeply into the bed. Therefore a clean section of the sand is available for the sub-surface members to use and the filter is capable of doing double the performance of the former practice.

GENERAL REMARKS

Old filter plants can be remodelled to contain this intermediate section of filtering and washing near the upper surface of the bed, and give increased capacity at a small expense against building new filters. When this is done the general view of the illustrated construction applied need not be followed explicitly because there will be some designs which can better employ connecting the piping gallery lines for the additional wash and filtering. But the general view here illustrated is believed to be a cheaper application than breaking into the piping gallery for this purpose because there is not required the heavy cast iron pipes and flanged valves for the light pressure used in the washing and filtering action in gravity filters.

In building new plants, also, this condition may not be the best because the wash troughs can be constructed in double section so the sub-surface supply header can be a part of the trough and constitute its lower section and separate this water from the inlet and drain which troughs now provide. This construction will omit the appearance of the main supply header entirely and the filter appearance then will be unusual only in that it contains the slotted pipes protruding upward to wash the expanded sand.

IMPROVED WASHING OF OLD FILTER PLANTS WITHOUT INCREASING FILTRATION CAPACITY

There are many filters which are now not satisfactorily washing and which resort to hand methods of cleaning at certain intervals when the mud ball accumulation makes additional washing of the unit necessary in order to continue the filtration. In these plants it is possible to construct only a portion of the sub-surface improvement, namely, the portion devoted to top washing of the bed in addition to the reverse wash from below. This involves everything shown on the general illustration with exception of attaching the sub-

surface members below the bed. The system of top washing into the expanded portion of the bed by using the slotted pipes is effective for keeping the filter sand clean, of continuing the filtration practice without difficulties and avoiding hand operation in doing so. For instance, a plug can be inserted in the tee fitting which is shown in the sub-surface member enlarged view on the right side of the general illustration, and then when additional filtering is needed this plug can be removed and the sub-surface member attached to the line. Then the system can be used for both filtering and washing. It is therefore possible to improve the old plants to make them free of mud balls and in condition for a good wash and filtering operation without the expense of adding the entire system when additional filtering is not needed. The expense of the filtering feature is thus avoided and the sub-surface improvement is applicable to wash the filters in a more perfect manner than can be done when using the reverse practice alone. This is for the reason that high velocity wash simply expands the sand and separates the sand grains without scouring or rubbing them together and fails to produce an agitating effect which is necessary to get rid of mud balls. These mud balls start small and become larger as time continues and eventually break down the filter entirely for the purpose of its use in filtration. These small mud balls are frequently about $\frac{1}{4}$ to $\frac{1}{2}$-inch in diameter and cannot lift up with the reverse wash to escape in the troughs. They therefore hang back in the sand and require cleaning by hand. They are not removed by any velocity of washing water from reverse flow when used alone.

My experience has shown that penetration of impurities, with good floc condition and proper size of sand is confined to within six inches of the surface. The same condition of penetration surrounds the sub-surface filters. This leaves the balance of the filter performing no action in filtration but simply as a carrying channel or means to escape for the filtered water. The actual filtration is done only through the three to six inches of sand surface both upon the surface and within the bed.

This penetration can be more or less controlled by variation of the conditions of floc formation (with its good or bad quality); by the coarseness or fineness of the filter layer; by the kind of filter material used; and, by the rate of flow employed for filtering. This assumes that in all cases complete washing of the filter to a clean condition is provided.

Analysis of the filter sand at Kenilworth, Illinois shows the top surface first quarter quarter inch to have an effective size of .468 m.m. and 12 inches below— .530 m.m. The top surface uniformity coefficient is 1.24 and 12 inches below is 1.27. It is this feature which I would call to your special attention, namely, that the uniformity coefficient at the surface and 1 foot below is so low that good retention of impurities retained in the floc and at the interstices of the sand grains is practically uniform. For this reason it produces good filtration surrounding the sand of the sub-surface filters as well as upon the top surface of the unit. Whether or not it is for this reason that good bacterial results are obtained by this means is not definitely established. But it is true that the washing action of boiling and throwing the sand around at its upper section and expanded portion changes conditions so that the hydraulic condition of routine practice does not exist and the finer sand is not all at the top surface.

There has been a plant recently built at Denver rated at 2.8 g.p.m. per square foot which is 175 m.g.a.d. rate. This plant further confirms the idea that, when micro-organisms and turbidity are low so that excessive loading of the sand bed does not occur (such as with adequate settling chambers and good quality coagulation), our present practice of operating at 2 gallons per square foot per minute does not constitute the best which is possible today.

W. V. Weir, Superintendent of the St. Louis County Water Co., placed a new filter plant in operation on January 21, 1938. It includes eight 4½ m.g.d filter beds rated at 3 gallons per sq. ft. per min., with Wheeler bottoms, 12 inches of gravel and 27 inches of sand— .45 to .50 m.m. size.

Concerning filtration rates, I wish to mention that during my work at the Louisville filtration experiments I made a test run (No. 154) at the rate of 220 m.g.a.d., with good bacterial results. It is my memory of that work 42 years ago, which prompted me to do this new work today of increasing the capacity beyond the present conventional practice.

CINCINNATI REPORT BY FULLER ON JEWELL FILTER

It was later reported by Mr. Fuller that Cincinnati filters could operate as high as 170 m.g.a.d. satisfactorily, and in the Report on Water Purification, Cincinnati, dated 1899, of Mr. Fuller's work, it is stated (page 367):

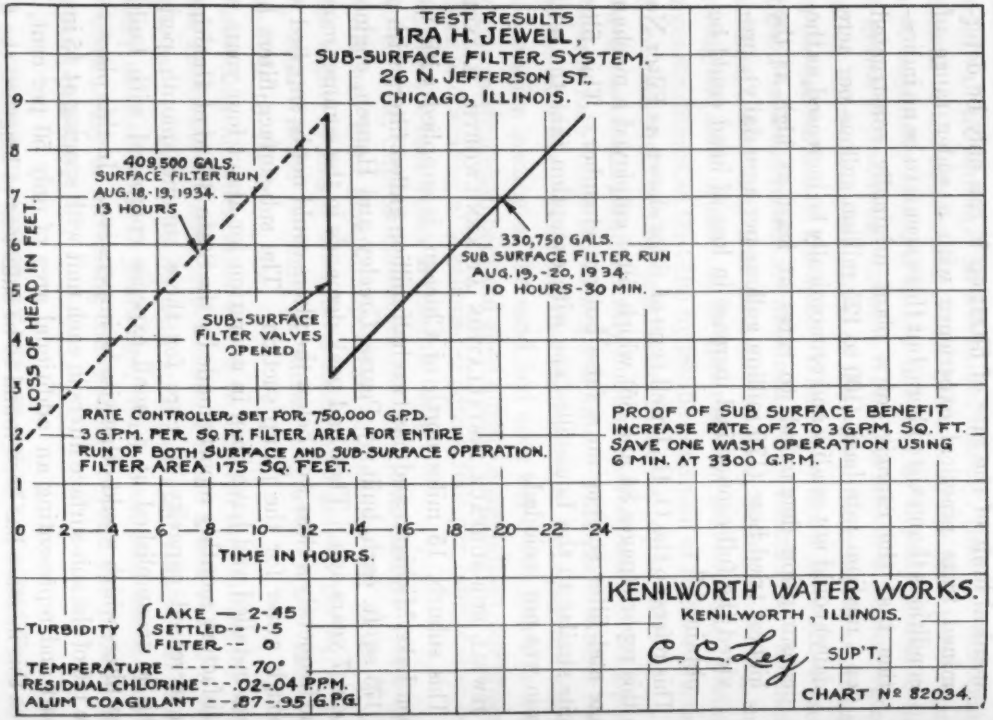
> "It may be concluded that high rates are more economical than low ones, and that the full head which can be used efficiently should be provided. Just where the economical limit of the rate of filtration is can only be determined from practical experience with a wider range of conditions than existed here, but there seems to be no indication that the capacity of a plant originally constructed on a medium rate basis (100 to 125 million gallons per acre daily) could not readily and economically be increased, as the consumption demanded, to rates at least as high as the highest tried here (170 million gallons per acre daily), provided the full economical increase in loss of head could be obtained."

This refers to the O. H. Jewell type of filter shown as Filter No. 20 in this report (pages 84 and 85) which filter employed a mechanical rake and filter screens on a false bottom chamber. This filter is quite similar to the Louisville type with exception that the settling basin was not included.

JEWELL SUB-SURFACE INSTALLATION AT KENILWORTH, ILLINOIS

This suburb, 15 miles north of Chicago, is supplied with water from Lake Michigan and has two half million gallon filters with area of 175 sq. ft. each, built by Pearse, Greeley and Hansen, engineers, about 7 years ago. They had peak demands in the summer months and frequently a clear well below the filters could not be supplied with enough water for the pump suction. The sub-surface filters have been installed and have been in operation for about four years with satisfactory monthly reports made by the State Board of Health and an increased capacity to care for these summer month periods. This is accomplished at a small expense compared with building new filters which would otherwise be imperative. In this plant there are 110 of the sub-surface filters in each unit with spacing at 15 inches apart and representing an additional area of only 50 per cent, but even this increase has been found to be sufficient to lengthen the filter runs or double the capacity for short periods.

Data to support this statement are shown in accompanying charts 82034 and 82035, which indicate, for the sub-surface system, double the length of time for filter runs or double capacity can be obtained, whichever choice of operation may be taken as preferred.


TEST RESULTS
IRA H. JEWELL,
SUB-SURFACE FILTER SYSTEM.
26 N. JEFFERSON ST.
CHICAGO, ILLINOIS.
LOSS OF HEAD IN FEET.
409,500 GALS.
SURFACE FILTER RUN
AUG. 18, 19, 1934.
13 HOURS.
SUB-SURFACE
FILTER VALVES
OPENED
330,750 GALS.
SUB SURFACE FILTER RUN
AUG. 19, -20, 1934
10 HOURS-30 MIN.
RATE CONTROLLER SET FOR 750,000 G.P.D.
3 G.P.M. PER SQ FT. FILTER AREA FOR ENTIRE
RUN OF BOTH SURFACE AND SUB-SURFACE OPERATION.
FILTER AREA 175 SQ. FEET.
PROOF OF SUB SURFACE BENEFIT
INCREASE RATE OF 2 TO 3 G.P.M. SQ. FT.
SAVE ONE WASH OPERATION USING
6 MIN. AT 3300 G.P.M.
0 — 2 — 4 — 6 — 8 — 10 — 12 — 14 — 16 — 18 — 20 — 22 — 24
TIME IN HOURS.
TURBIDITY { LAKE — 2-45
SETTLED-- 1-5
FILTER-- 0
TEMPERATURE ------ 70°
RESIDUAL CHLORINE ---.02-.04 P.P.M.
ALUM COAGULANT --.87-.95 G.P.G.
KENILWORTH WATER WORKS.
KENILWORTH, ILLINOIS.
C. C. Ley SUP'T.
CHART Nº 82034.

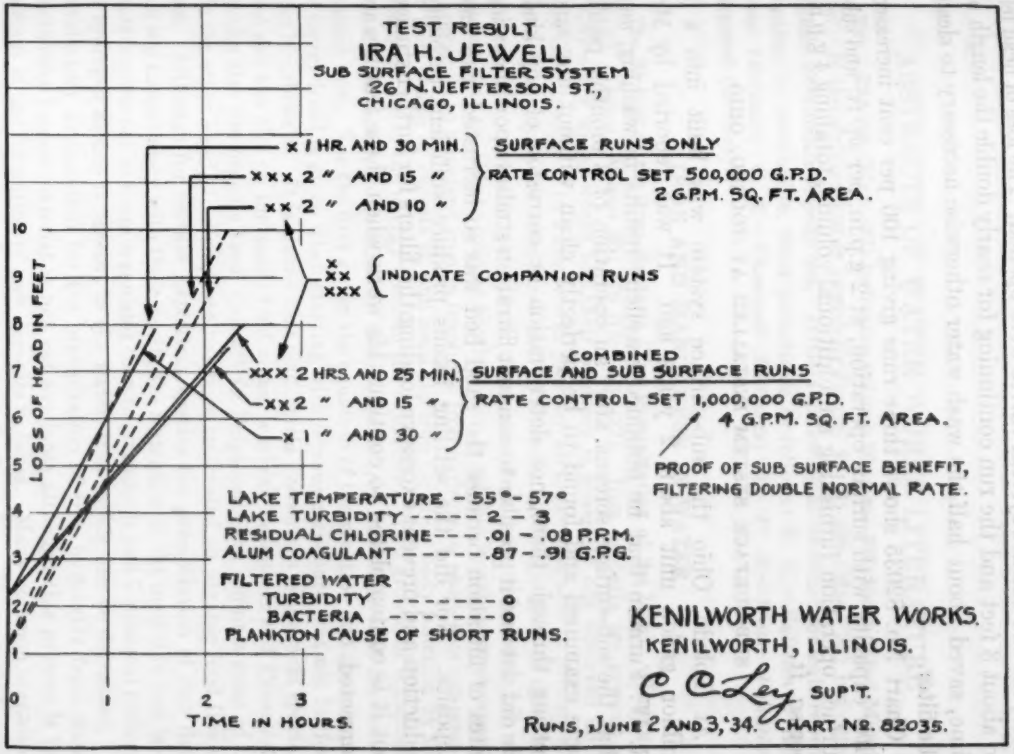

TEST RESULT
IRA H. JEWELL
SUB SURFACE FILTER SYSTEM
26 N. JEFFERSON ST.,
CHICAGO, ILLINOIS.
x 1 HR. AND 30 MIN.
xxx 2 " AND 15 "
xx 2 " AND 10 "
SURFACE RUNS ONLY
RATE CONTROL SET 500,000 G.P.D.
2 G.P.M. SQ. FT. AREA.
x
xx
xxx
INDICATE COMPANION RUNS
COMBINED
xxx 2 HRS. AND 25 MIN.
xx 2 " AND 15 "
x 1 " AND 30 "
SURFACE AND SUB SURFACE RUNS
RATE CONTROL SET 1,000,000 G.P.D.
4 G.P.M. SQ. FT. AREA.
PROOF OF SUB SURFACE BENEFIT,
FILTERING DOUBLE NORMAL RATE.
LOSS OF HEAD IN FEET
TIME IN HOURS.
LAKE TEMPERATURE - 55°- 57°
LAKE TURBIDITY ----- 2 - 3
RESIDUAL CHLORINE--- .01 - .08 P.P.M.
ALUM COAGULANT ------ .87 - .91 G.P.G.
FILTERED WATER
TURBIDITY -------- 0
BACTERIA -------- 0
PLANKTON CAUSE OF SHORT RUNS.
KENILWORTH WATER WORKS.
KENILWORTH, ILLINOIS.
C. C. Ley SUP'T.
RUNS, JUNE 2 AND 3, '34. CHART NO. 82035.

Chart No. 82034 shows operation at 3 g.p.m. per sq. ft. until the loss in head gauge advanced to 8½ feet. Then instead of washing the filter, the sub-surface system valves were opened. The loss of head fell to about 3 feet and the run continuing for nearly double the length of time, saved about half the wash water otherwise necessary to clean the filter.

Chart No. 82035 shows three runs giving 100 per cent increased filter capacity with surface operation, at 2 g.p.m. per sq. ft. and sub-surface operation furnishing an additional volume, totalling 4 g.p.m. per sq. ft.

SUB-SURFACE SYSTEM INSTALLED AT TOLEDO, OHIO

At Toledo, Ohio the sub-surface system was built into a 1 million gallon unit about 2 years ago. It was reported by Mr. R. W. Furman that he obtained excellent results in washing, and that the sub-surface screens after an operation of 8 months' period were examined and found to be perfectly clean without any sand getting through them, nor deterioration or corrosion of any kind. He did not find it possible to conduct filtration studies upon increasing rates of filtration because the sand bed was so incrusted with lime deposits. Nor did the settling basins produce sufficient turbidity reduction and prevent excessive loading the filters for further studies, but it is contemplated to continue his work when these features are corrected.

ABSTRACTS OF WATER WORKS LITERATURE

Key. 29: 408 (Mar. '37) indicates volume 29, page 408, issue dated March 1937. If the publication is paged by issues, **29:** 3: 408 (Mar. '37) indicates volume 29, number 3, page 408. Initials following an abstract indicate reproduction, by permission, from periodicals as follows: B. H.—*Bulletin of Hygiene (British)*; *C. A.—Chemical Abstracts*; *W. P. R.—Water Pollution Research (British)*.

IRON AND MANGANESE IN WATER

The Biology of the Iron-Bacteria (The Precipitation of the Iron). HERBERT BEGER. Gas-u. Wasser **80:** 779 (Oct. 23, '37). Iron bacteria are present in nearly every water-works but their presence is generally not observed until they start trouble. In water-works practice all organisms able to precipitate iron or manganese are considered as iron bacteria, although a few of them are really molds. Actually only those organisms should be considered iron organisms that are able to oxidize bivalent iron in soluble bicarbonate or organic compounds to trivalent iron in insoluble iron hydroxide, store this compound in their bodies or excrete it, and need the iron for their body function by the biological use of the energy freed in the oxidation. Two groups of organisms are differentiated, those that can use inorganic iron and those that depend on organic iron. For the first group the equation of the reaction and the amount of energy freed is given when starting with ferrous carbonate, but not for ferrous bicarbonate. It is stated that *Gallionella Ferruginea* is the most specialized and can live on inorganic food alone, whereas *Leptothrix* and *Crenothrix* species also use organic food, *Crenothrix Polyspora* even requires some of it. On the other hand, *L. discophora* has been cultivated on organic food free of iron. Although for certain *Leptothrix* species the precipitation of iron does not end immediately with their death, the formation of the insoluble iron is of more importance to these organisms than to consider it just a chemical process. If hydrogen sulfide is present in the water, iron sulfide can be deposited. A satisfactory explanation for the precipitation of iron hydroxide from water containing humus material is not yet available although this process is important in the formation of iron deposits in lakes. Many common organisms can precipitate some iron from organic iron double salts. There are at present 46 recognized and named iron organisms belonging to many bacterial groups. Iron bacteria occurs in fresh and sea water, in surface and underground water, in clear and in heavily polluted water, others in slightly alkaline water, some in cold, others in warm water, one even grows in hot springs. Organisms that are attached to a surface prefer flowing water and the free flowing develop better in standing water. Each species has its special preferences.—*Max Suter.*

Iron Bacteria in Water Works and their Practical Significance. HERBERT BEGER. Gas-u. Wasser **80**: 886 (Dec. 11, '37.) Methods for the collection and examination of iron bacteria are described. Illustrations and data are given for identification of 14 species occurring mainly in water-works. Most iron bacteria infect the water-works through the raw water but infection from the outside is not impossible. Only those species can develop in the water-works that are able to live in the limited range of conditions present during and after treatment. Mass development is now very rare; may occur in raw water lines and on filters. In mains carrying purified water *Gallionella Ferruginea* is mainly found, occasionally *Leptothrix ochracea* and *L. trichogenes*. *Gallionella ferruginea* prefers cold water of low iron content and can form spongy incrustations in the pipes. Pure cultures of the iron organisms are very difficult to obtain. Some forms however can be cultivated in raw cultures, yet the conditions for their experimental development are as yet uncertain.—*Max Suter.*

The Biology of the Precipitation of Manganese by Iron Bacteria. HERBERT BEGER. Gas-u. Wasser **81**: 35 (Jan. 15, '38). Most iron bacteria can also precipitate manganese. *Gallionella ferruginea* is a pure iron precipitating organism. Mainly iron precipitating are also *Leptothrix ochracea, L. trichogenes, Siderococcus limoniticus,* several *Siderocapsa* species. Manganese liking organisms are *Leptothrix discophora, L. echinata* and *L. lopholea.* Manganese preferring are *Crenothrix polyspora* and *Cr. fusca,* whereas *Bacillus manganicus* and a few other single cell organisms seem to precipitate only manganese. The more the organisms prefer manganese, the more they require a water containing an organic source of carbon as measured by the potassium permanganate test. An exception is *Crenothrix fusca,* which avoids even slightly polluted waters. As manganese is much more difficult to remove chemically than iron, the Vollmar filter was developed in Dresden, in which the filter sand contains manganese dioxide and is inoculated with manganese precipitating organisms. Owing to the difficulty of controlling the activity of these organisms, dependence is no longer placed on their presence. Yet they may play a rôle in any manganese removing processes which are assumed to act only chemically, as prechlorination must then be avoided and a certain time is required to start the action. The energy freed in the oxidation of manganese carbonate to manganese hydroxide is less than one-third of that freed in the oxidation of an equivalent amount of ferrous carbonate. This may explain why the organisms precipitate more manganese in their bodies than iron and grow so much more prolifically that *Crenothrix polyspora* growing in water containing manganese has been considered as a separate species *Cr. manganifera.* (Jackson 1902). Besides the thread bacteria many *cocci, diplococci* and rods precipitate manganese. Trouble in water-works is often caused by shiny deposits formed by capsulated organisms often difficult to identify. Several such cases are reported, partly from the literature and partly from the author's own investigation.—*Max Suter.*

The Economic Cost of Waters Containing Iron and Manganese. HARTWIG KLUT. Gas-u. Wasser **81**: 4 (Jan. 1, '38). The presence of iron and man-

ganese is becoming more and more important owing to the damages done by these substances. Surface waters as a rule contain little iron or manganese, but both of these substances are very common in ground water. They are present mainly as carbonates, sometimes as humates, that is in organic form, occasionally as sulfates and chlorides especially in mine discharges. Iron can be present up to 20 p.p.m. whereas manganese seldom is present over 1 p.p.m. Three-tenths p.p.m. of iron carbonate gives the water an inky taste, 0.5 p.p.m. of iron humate gives it a marshy earthy taste, iron hydroxide is practically without taste and manganese gives a metallic taste if present over 0.5 p.p.m. The ferrobicarbonate dissolved in the water oxidizes easily if exposed to air giving off CO_2 and forming ferric hydroxide. If carbonate hardness is present in the water this oxidation and the precipitation of the hydroxide take place in a few hours; in soft waters and waters containing humus it may take days or weeks. Manganese precipitates very seldom on exposure to air. Iron and manganese have no harmful effect on the health except in the cases of sensitive small children who may lose appetite. Horses seem to be more sensitive to a change in the iron content of the water. Iron and manganese in the water favors the growth of certain microscopic organisms (*Crenothrix, Gallionella, Lepthrothrix*, etc.) which may reduce the capacity of the distribution system. To avoid such troubles the water should contain not over .1 p.p.m. Fe = .143 p.p.m. Fe_2O_3 and less than .1 p.p.m. Mn. Economically the water should be practically free of iron and manganese and this it is technically possible to obtain. Examples of trouble caused by iron content are: coloring of pans and bathtubs, tastes in drinks, coloring on sprinkling or in fountains, effect on laundry. If the water is chlorinated a manganese content of 0.05 p.p.m. has a detrimental effect. Industries like bakeries, bleacheries, printing and dyeing plants, breweries, distilleries, ice plants, glassworks, white porcelain plants, starch and sugar refineries and photographers require iron free water to avoid discolorations. In the canning industry an iron content of the water may cause tastes. The sludge produced in iron removal plants is mostly wasted, although it can be used for the purification of artificial gas and to give color to ceramic products. For many other uses, especially for metallurgical purposes, the sludge contains too many impurities.—*Max Suter.*

Some Conditions Governing the Solubility of Iron. L. H. N. COOPER. Proc. Roy. Soc. (London) **B124:** 299 ('37). Max. activity of Fe^{++} cation is controlled by activity of Fe^{+++} cation and oxidation-reduction potential of system. Total amt. of Fe in true soln. in water after equil. has been attained does not exceed, in mg. Fe per cu. m., 3×10^{-6} at pH 8.5, 4×10^{-7} at pH 8.0, 4×10^{-5} at pH 7.0, 5×10^{-3} at pH 6.0; cations are chiefly Fe^{++} and $FeOH^{++}$, in more acid solns. Fe^{+++} is important. These values apply to Fe in sea water, natural waters, etc.—*R. E. Thompson.*

Well Supply Aerated to Remove Iron, and Softened with Zeolite. THEODORE REED KENDALL. Am. City **53:** 3:49 (Mar. '38). The WPA financed water-treatment works at Bicknell, Indiana consists of three wells, three circular coke-bed aerators, settling basin, filters, zeolite softeners, chlorinator, pumps

and elevated storage tank. The raw water contains 30 g.p.g. hardness and 6.0 p.p.m. iron. Effluent to consumers contains 4 g.p.g. hardness. Amount of iron removal is not given.—*Arthur P. Miller.*

Aeration and Sedimentation Remove Iron from Water. ANON. Am. City **53**: 2: 33 (Feb. '38). By means of aeration in a coke-filled multiple aerator and long sedimentation, the iron content of the water supply of Jackson, Tennessee is reduced from 3 p.p.m. iron and 85 p.p.m. CO_2 to 0.2 and 8.0 respectively. A reduction in pumpage from 4¾ to 1½ million gallons for a Sunday in cool weather over the corresponding Sunday a year previous is accredited to the installation of meters on 75% of the services.—*Arthur P. Miller.*

Iron Bacteria in the Drinking Water of Buenos Aires. MARIA S. CATALDI. Bol. Obras Sanit. Nación (Buenos Aires) **1**: 464 ('37). *Leptothrix ochracea* and *Antophysa vegetans* were found in La Plata river. They were absent in samples collected from the water reservoirs after Cl treatment.—*C. A.*

Data on Etobicoke Township Softening Plant. W. H. WALKER. W. W. Inf. Exch., Canadian Sect., A.W.W.A. **2**: A: 1: 11 (Nov. '37). Data regarding the zeolite softening plant constructed in '32, the first municipal installation in Canada, are given. Water supply is derived from 2 deep wells, the water containing 320 p.p.m. hardness and 1.4 p.p.m. iron. Delivered water (90% treated and 10% raw) contains 80 p.p.m. hardness and 0.3 p.p.m. iron. Plant consists of 4 pressure units, 11′ high and 6′ diam., containing natural zeolite. Water used for regeneration and backwashing averages 8.5% and salt consumed per 1000 grains of hardness removed and per 1000 gals. of water delivered 0.37 and 6.11 lbs., respectively. The cost of plant operation and supervision per 1000 gals. is 1.74¢, cost of water at plant 6.95¢ and total cost of treated water, including fixed charges, 11.8¢. These data based on '35 consumption of nearly 0.5 m.g.d. As consumption increases, costs will be lower: in '36, with consumption about 25% higher, fixed charges were 1.05¢ per 1000 gals. less. Chlorination not required. Population served 10,000.—*R. E. Thompson.*

Some Operating Experiences With Iron and Iron Coagulants in Water Treatment. MALCOLM PIRNIE. J.N.E.W.W.A. **51**: 437 (Dec. '37). Difficulty in oxidation of iron has hindered both Fe removal from water and use of Fe coagulants. Recent additions to coagulants are ferric chloride, anhydrous ferric sulfate and chlorinated copperas. *Copperas* (ferrous sulfate) has been commercially available for many yrs. Dissolves readily into corrosive soln. which may be handled in lead-, rubber-, or glass-lined pipes or tanks. Can be fed dry. 1 part chlorine to 7.8 parts copperas gives converted soln. containing ferric chloride and sulfate. *Ferric Chloride.* Purchaseable as conc. soln. (40% $FeCl_3$), lumps, cake and anhydrous powder. Readily soluble, soln. should be stored in rubber-, lead-, or glass-lined tanks. *Ferric Sulfate.* Grey, fine, gravel-like material which can be readily stored and fed in dry feed machines. To put into soln. warm water must be used, conc. maintained at 40–60% and soln. kept agitated by stainless steel-, hardwood-, lead-, or rubber-covered paddle. Ferric sulfate or chloride introduced into water

containing dissolved oxygen forms ferric hydroxide over pH range of 4 to 10. Coagulation of soft waters for boiler use with ferric sulfate at low pH has been found beneficial as substantial removal of silica is obtained and the sulfates introduced aid control of embrittlement. Experience with several supplies is detailed. *Long Beach, L. I.* Water from artesian source, little or no Ca and Mg, about 10 p.p.m. SiO_2, 7 p.p.m. Fe, and CO_2 content of 40 p.p.m. After aeration water passes upward at 2 gal. per sq. ft. per min. rate through 9′ graded silica gravel. Filtration liberates 10 p.p.m. CO_2 and reduces Fe to less than 0.10 p.p.m. Beds washed downward when 3′ loss of head reached under 12′ head of water. Upward wash at 4′ per min. rise provided for and used occasionally. *Stuart, Fla.* Similar plant used for water containing 4.5 p.p.m. Fe and alk. of 150 p.p.m. Found necessary here to delay action of precipitation of Fe until water reached contact beds, accomplished by reducing aeration. Only 1 hr. operation time given this plant daily and it and other similar plants constructed for Fla. utility have been very satisfactory. Soft Colored Waters Containing Iron and Manganese: During '28 and '29 av. Fe content of *Providence, R. I.* raw water was 0.65 p.p.m. reduced late in '29 to 0.27 p.p.m. by changing intake to higher lake level. Manganese then found and ferric-iron coagulation studies made for purpose of removing this element. By use of anhydrous ferric sulfate and ferric chloride, av. Fe content of filter eff. and city tap water has been 0.03 p.p.m. Av. use of chemicals (lbs. per mil. gal.), has been with alum, copperas, chlorinated copperas, anhydrous ferric sulfate and ferric chloride respectively: 77.5 lbs. coagulant and 29.6 lbs. lime for pH 8.14; 156.7 lbs. coag. and 181 lbs. lime for final pH 9.7; 109.7 coag., 15.39 lbs. chlorine and 134.2 lbs. lime, final pH 9.6; 85.2 lbs. coag. and 137.5 lbs. lime, pH 9.56; 59.6 lbs coag. and 146.9 lbs lime, pH 9.5. Partial Softening of Hard Water Low in Sulfates: Pinellas Water Co. (*St. Petersburg, Fla.*) is under contract to supply water of 160 p.p.m. max. total hardness; since '35 has furnished water of 100 hardness. Lime used for softening, ferrisul for coagulation in 7 m.g.d. cap. unique plant, one feature being upward-flow settling basins. (See J.A.W.W.A. **29**: 2075 (Dec. '37).) In '35–'37 the 2031.16 mil. gal. water treated req'd an av. of 665 lbs. of lime and 97.6 lbs of ferrisul per mil. gal. Highly Colored Swamp Water: In an industrial plant in S. C. it was desirable to design present purification method with coagulation alone for possible later inclusion of more complete treatment including filtration. Demonstrated it is possible to reduce color from 170 to 10 p.p.m. or less with anhydrous ferric sulfate at pH 4, total alk. of raw water being 4 and pH 6.4. Also shown treatment removed substantial amount of silica. Upward flow coagulation tanks used. Colored Soft Water Containing no Manganese: *West Palm Beach, Fla.* surface water mixed with well water to get good coagulation. Alum used and because well water is effective in producing necessary delicate adjustments of alk. to insure complete precipitation of aluminum, no improvement can be made by change to Fe coagulant. Experiments with a water containing acid mine drainage are briefly described as is experience with a small treatment plant on private estate. Author believes progress in improvement of water supplies from physical standpoint will continue for yrs. to come.—*Martin E. Flentje.*

Determination of Iron. With 7-Iodo-8-hydroxyquinoline-5-sulfonic Acid. H. W. SWANK WITH M. G. MELLON. Ind. Eng. Chem.-Anal. Ed. **9**: 406 (Sep. '37). 7-iodo-8-hydroxyquinoline-5-sulfonic acid (ferron) is suitable for colorimetric determination of small quantities of ferric iron (order of 0.2 to 1.0 p.p.m.) but careful control of experimental conditions is necessary. pH may be between 2.0 and 3.0 but given series must be buffered to 0.2 pH unit if error is not to exceed 2%. Color is permanent for at least a week even in diffuse daylight. Interference is caused by any anions forming complexes with iron or any cations reacting with ferron, even though reaction product is colorless. Photoelectric recording photometer was used in studies reported.—*Selma Gottlieb.*

Colorimetric Microdetermination of Manganese. C. P. SIDERIS. Ind. Eng. Chem.-Anal. Ed. **9**: 445 (Sep. '37). Manganese is determined by formaldoxime reagent of Denigés. Interference of iron is eliminated by addition of sodium cyanide, then matching resulting greenish color by addition of cyanide and iron to blank. Using colorimeter, 0.25 to 20γ of manganese were accurately determined.—*Selma Gottlieb.*

Determination of Iron with o-Phenanthroline. W. B. FORTUNE WITH M. G. MELLON. Ind. Eng. Chem.-Anal. Ed. **10**: 60 (Feb. '38). Using photoelectric spectrophotometer, 0.1 to 6 p.p.m. of iron can be dtd. in 1.00 cm. comparison cell by o-phenanthroline (I) method of Saywell and Cunningham. Visual comparison is also applicable since color reaction conforms to Beer's law over entire concn. range studied. Hydroxylamine hydrochloride is best reductant found; 0.1 ml. of aqueous 10% soln. is needed to reduce 1 p.p.m. of ferric iron to ferrous. Six ml. of aqueous 0.1% soln. of (I) are needed to give max. color with 5.0 p.p.m. of iron. pH has no effect over applicable range of reaction, 2.0 to 9.0. Color is stable for six months. Of 55 possibly interfering ions studied, very few interfered. Most ions commonly found in water were harmless, though 20 p.p.m. of zinc gave ppt. with (I), preventable by using excess of (I).—*Selma Gottlieb.*

Determination of Iron with Mercaptoacetic Acid. H. W. SWANK WITH M. G. MELLON. Ind. Eng. Chem.-Anal. Ed. **10**: 7 (Jan. '38). With mercaptoacetic acid, iron gives reddish purple color which is suitable for detn. of small amounts of iron. Reagent contains 10% by vol. of the acid and is neutralized with ammonia. 2 ml. of reagent and 10 ml. of 3 *N* NH_4OH are added to sample and made to 100 cc. for comparison with standards. Color is not sensitive to exact reagent concn. or pH, is reproducible and is stable for several hours. Method is free from interference by many ions which affect other methods, but certain cations interfere, including those pptd. by NH_4OH.—*Selma Gottlieb.*

Colorimetric Determination of Iron with Salicylic Acid. Spectrophotometric Study. J. P. MEHLIG. Ind. Eng. Chem.-Anal. Ed. **10**: 136 (Mar. '38). Study of dtn. of Fe with salicylic acid was made, using photoelectric spectrophotometer, which yields entirely objective color measurements free from personal error, and capable of high accuracy and precision. Color standards were

prepd. as follows: To 5 ml. of slightly acid standard Fe soln. contg. 0.1 mg. of ferric iron per cc., add 1:1 NH_4OH drop by drop to almost neutralize, followed by 1 ml. of Na salicylate soln. (10 grams per 100 ml. of water), make slightly alk. with 1:1 NH_4OH and then just acid by dropwise addn. of 1:1 acetic acid. Add 10 ml. of 1:1 acetic acid and make to 100 ml. with distd. water. Study showed method is satisfactory if exptl. conditions are carefully controlled. Optimum pH is 2.6 to 2.8. Not more than 1 ml. of Na salicylate soln. and 12 ml. of 1:1 acetic acid should be used. Color follows Beer's law and is stable in diffuse light for 66 hrs. 10 p.p.m. of fluoride causes apparent decrease of 15.4% in 5 p.p.m. of Fe. Effect of 2500 p.p.m. of Cl or SO_4, 2000 p.p.m. of NO_3 or CO_3, 500 p.p.m. of Ca, 1000 p.p.m. of Mg or 2600 p.p.m. of Na is negligible, though numerous cations and anions interfere.—*Selma Gottlieb.*

COPPER AND LEAD IN WATER

Conclusions of the Commission for the Examination of Copper Pipe. Verein fur Wasserversorgungsbelange in Holland. Wasser u. Abwasser **35**: 188 ('37). Cu content of water from Cu pipes which have been in use at least 3 months must not exceed (a) 3 mg. per liter for water which has stood in the pipe 16 hours; (b) 2 mg. per liter for normal flowing tap water Arsenic must not exceed (a) 15 μ per liter, (b) 10 μ per liter.—*C. A.*

Water and Sewage in Relation to the Public Health. WARREN J. SCOTT. J. Conn. State Med. Soc. **2**: 148 ('38). In Connecticut, soln. of metals by water seldom is a cause of sickness, and no instances of Cu poisoning by water have been reported. On rare occasions corrosive waters such as have been found in some private spring supplies have attacked Pb pipe to the extent of dissolving sufficient Pb to cause Pb poisoning. Pb service pipes widely used in some cities to connect street mains and house water piping systems appear to have rapidly developed a protective inner coating, without causing trouble. At present, Pb service pipes are seldom installed on public water systems in Connecticut. The soln. of Cu in sufficient amts. to result in Cu poisoning will not ordinarily occur unless so much Cu is dissolved as to impart an objectionable metallic taste to water which will render it almost unusable. There is to date no information available from water analyses or observations that fluorides occur in troublesome amts. in Connecticut waters.—*C. A.*

The Injurious Effects of Some Waters which Corrode Metals. JOSEF KOBLICE. Chem. Obzor, **12**: 132 ('37). Water in a laundry left a light tarnish upon the washed goods. Change in source of water did not correct difficulty. Complete elementary analyses of the waters (presented in tables) did not reveal unusual composition. Later investigations showed that the water dissolved traces of copper from the copper heaters and tubes which adhered to the cloth fibers and which, during the boiling process, became reduced to the form of a fine precipitate, imparting the effect noted. The water contained 1.36 p.p.m. of copper, 0.02 p.p.m. of iron and 0.01 p.p.m. of manganese. Corrosiveness of water is ascribed to its unusual softness, activated oxygen in solution and the content of carbon dioxide. Similar difficulties might be experienced in small laundries or in the household.—*R. E. Thompson.*

Demonstration and Determination of Copper by Color Reactions. PIERRE THOMAS. Biochem. Z. **293**: 396 ('37). In acid soln., Cu in concn. up to 2×10^{-6} gives a reddish turbidity with $K_4Fe(CN)_6$. With hematoxylin, Cu salts give a blue color, but reaction is not sensitive below a concn. of 10^{-7} and is very much affected by changes in pH. An alk. soln. of formaldoxime, which gives with Cu a deep green color, is an excellent reagent. With very small amts. of Cu a violet color is obtained which is proportional to the amt. of Cu. Reagent is prepd. by dissolving 2 grams $NH_2OH \cdot HCl$ and 2 cc. HCOH in a 100 cc. vol. It yields a recognizable test even with a 3×10^{-7} diln., provided the medium is alk. and excess reagent is avoided. Urobilin gives a red color reaction which permits detn. of 1 γ Cu. However, reaction which Cu gives with an alk. soln. of phenolphthalein has been found even more sensitive and suitable for colorimetric detn. of Cu. reaction being pos. even with a 10^{-6} diln. or 0.01γ/cc., whereas with urobilin the reaction is no longer obtained in this diln.—*R. E. Thompson.*

Presence of Lead in Drinking Water. F. DIÉNERT. Usine franc. **46**: 21: 39 ('37). Discusses toxic effect of lead in drinking water, and describes cases of poisoning in different countries, giving analyses. In France lead pipes must not be used if a water contains less than 100 mg. calcium carbonate per liter, as no protective layer will be formed, especially if oxygen, carbon dioxide, nitrates or chlorides are present. The use of pipes of a lead-tin alloy has been suggested but is restricted by their cost.—*W. P. R.*

Determination of Copper in Milk and Dairy Products. JOSEF KRENN. Mikrochemie **23**: 149 ('37). After destruction of organic matter and removal of Ca and phosphate by addn. of liberal excess of NH_4OH, filtrate is evapd. to dryness, residue taken up in a little HCl, soln. evapd. just to dryness again, Cu pptd. as $Cu(C_5H_5N)_2.(CNS)_2$ by treatment with NH_4CNS and pyridine, ppt. dissolved in $CHCl_3$ and green soln. used for colorimetric detn. of Cu. On samples contg. 0.27–1.17 p.p.m. Cu, excellent recovery of Cu was effected: greatest error was 0.02 mg. or 3–4% of actual Cu content.—*R. E. Thompson.*

FLUORINE AND SELENIUM IN WATER

Facts About Fluorides. H. TRENDLEY DEAN AND ELIAS ELVOVE. Eng. News-Rec. **120**: 591 (Apr. 21, '38). Chronic endemic dental fluorosis is waterborne disease caused by use of water containing in excess of 1 p.p.m. fluorine for drinking or cooking during period of dental susceptibility, i.e., from birth to 8 yrs. of age. There are 351 known or reported endemic areas in U. S., endemicity having been confirmed by survey in 260. Definite relationship has been established between fluorine content of water supply and incidence of affection. This is illustrated tabularly and graphically. In determination of small amounts of fluorine in water by Zr-alizarin method, it is advantageous not to introduce any more sulfate than is required to make standards and sample equal in sulfate concentration. The magnesium oxide method of removal, applied in 2 stages, will reduce fluorine from 5 p.p.m. to 1 p.p.m. or less, 1 lb. of magnesium oxide being required for each 88 gals. of water. Separate

precipitation of calcium and magnesium in the lime-soda softening method, as suggested by Hoover (This J. 29: 1687), might provide cheap source of magnesium oxide. Twenty-four references.—*R. E. Thompson.*

Fluorine Content in Mineral Water and its Fluctuation. YUTAKA SUGAWA. J. Chosen Med. Assoc. **27**: 1163. Analysis of 16 samples of mineral water collected from 8 Korean hot springs for F by the Elvove method shows that all but two contained F 0.8–10 p.p.m. Incidentally, if NaF is added to tap water, F ions diminish gradually, probably owing to adsorption of the ions by suspended matter in the water.—*C. A.*

Removal of Fluorides from Potable Water by Tricalcium Phosphate. HOWARD ADLER, GEORGE KLEIN, AND F. K. LINDSAY. Ind. Eng. Chem. **30**: 163 (Feb. '38). Experiments with synthetic and natural waters showed that fluoride content can be reduced to less than 1 p.p.m. by filtration through bed of 20 to 40 mesh tricalcium phosphate (TCP). Efficacy is ascribed to porous structure of TCP, giving high adsorptive capacity, though compound such as fluorapatite may be formed. TCP used was prepared from commercial phosphoric acid of high purity and milk of lime. F content up to 18 p.p.m. has no significant effect on capacity of TCP in grams of F removed per unit wt. before F content of effluent is greater than 1 p.p.m. For regeneration, 1% NaOH is used followed by water wash and neutralization with 0.7% HCl. Between 2.5 and 3% of the TCP is lost in each regeneration, and capacity declines with succeeding cycles, though TCP has more than twice capacity of activated alumina, both originally and after use. Capacity of TCP decreases somewhat as hardness of water increases though this is not considered serious. Between 6.5 and 8.5 pH values did not affect capacity of TCP, and pH of effluent was always approximately 7.0. With unit contg. 2.04 kg. of TCP, capacity of 3.84 grams of F per kg. was obtd. at flow rate of 4.5 liters per minute. Alternative method of treatment is pptg. TCP in water to be treated by adding lime followed by phosphoric acid to pH 7.0 to 7.5. When wt. of TCP pptd. was about 200 times F present, F was almost completely removed, and TCP so pptd. was found to have capacity of 6.05 grams of F per kg.—*Selma Gottlieb.*

Removal of Fluorides from Natural Waters by Calcium Phosphates. W. H. MACINTIRE AND J. W. HAMMOND. Ind. Eng. Chem. **30**: 160 (Feb. '38). Fluorides can be completely removed from solns. contg. 6 p.p.m. as NaF or CaF_2 by conversion to fluorapatite through action of tricalcium phosphate (TCP). For home treatment best method is addn. of 4 parts of high grade phosphate baking powder, monocalcium phosphate or triple superphosphate to 1000 parts of water, and then pptg. phosphate and fluoride together with small excess of lime. After boiling 15 min. or more, excess lime can be pptd. by aeration and soln. clarified by sedimentation or filtration. Experiments with various phosphate materials showed that formation of fluorapatite is best induced by flocculent hydrated TCP. Sufficiently extended cold agitation is effective but boiling is preferable. Filtration of fluoride through column contg. mixture of sand and TCP gave partial removals with some basic phosphates but not with others. Some samples contain too much soluble phos-

phate, others appear to be solid solns. of P_2O_5 and CaO. Partial removals were obtd. with calcined phosphate rock and fused white rock, but not with fused brown rock. Pptn. of TCP in presence of fluoride is best method in present state of knowledge due to uncertainty as to reactivity of commercial TCP samples, cost of reagent grades and their limited commercial distribution. —*Selma Gottlieb.*

Titration of Fluorine in Aqueous Solutions. R. J. Rowley and H. V. Churchill. Ind. Eng. Chem.—Anal. Ed. **9**: 551 (Dec. '37). In absence of interfering substances, fluorine can be titrated quantitatively with 0.1 *N* thorium nitrate in aq. instead of 48% ethyl alcohol solns. if pH is closely controlled between 2.9 and 3.1 with buffer contg. 9.448 grams of monochloracetic acid and 2.000 grams of NaOH in 100 cc. of water. 8 drops of 0.05% aq. Na alizarin sulfonate soln. are added to 100 cc. of soln. contg. 1 to 50 mg. of F, pH adjusted and 0.1 *N* thorium nitrate added to permanent pink. Blank detn. is similarly made. Equivalence of thorium nitrate is uniform throughout range of 1 to 50 mg. of F and endpoint is more definite in aq. than in alc. solns. With very small amts. of F, using 0.01 *N* thorium nitrate, titration is very sensitive to pH and optimum pH has not yet been definitely detd.—*Selma Gottlieb.*

Further Field Studies on the Selenium Problem in Relation to Public Health. M. I. Smith and B. B. Westfall. U. S. Pub. Hlth. Repts. **52**: 1375 (Oct. 1, '37). During Sept., '36, a field study was made of a selected group comprising 50 rural families in a highly seleniferous area in 4 counties of So. Dak. and Neb. Purpose was to determine the possibility of selenium intoxication in man in selenium-endemic regions. Analysis of many samples of locally produced foodstuffs entering the human dietary directly or indirectly, indicates that meat, eggs and milk, and vegetables when available, constitute the most important and most constant sources of selenium to which man is exposed in the selenium endemic region studies. Out of 44 samples of drinking water from wells varying in depth from 20 to several hundred ft., only about 23% showed the presence of selenium in the relatively small amounts of 5 to 33 micro-grams per 100 grams. No definite relationship between the depth of the well and the selenium content of the water could be discovered. 5 tables included.—*R. E. Noble.*

Selenium as a Potential Industrial Hazard. H. C. Dudley. U. S. Pub. Hlth. Repts. **53**: 281 (Feb. 25, '38). The discovery and widespread study of selenium as a causative and contributing factor in certain animal diseases have aroused the interest of investigators in the significance of the element as a potential industrial hazard. Author states that local water supplies contaminated by selenium may account for its appearance in the urine of persons residing in certain areas.—*R. E. Noble.*

Detection of Selenium. Application to Natural Waters. Georges Deniges. Bull. soc. pharm. Bordeaux **75**: 197 ('37). Selenite ion may be detected by the immediate formation of a red ppt. when a little of the solid material in a por-

celain dish is treated with drop of aq., 5% thiourea soln. and, after mixing, 1 drop of *N* HCl. Under same conditions, selenate ion yields a ppt. only after several min. For examn. of water, evap. 60-cc. sample to about 4 cc. and add 5 drops of HCl. Transfer residue to small graduated cylinder, make up to 6 cc., mix and filter. To 5 cc. of clear filtrate, add 2 drops HCl and 5 drops of thiourea reagent, boil, allow to cool for 5 min. and examine. Turbidity is produced with 0.05 mg. Se per liter. If water contains $NaHCO_3$, make just acid with HCl.—*R. E. Thompson.*

CHEMISTRY—GENERAL

Synthetic Zeolite. U. Bagnoli. Italian P. **342**: 908; Chem. Zbl. **2**: 3212 ('37). Synthetic zeolite may be prepared by calcining a mixture of 30–50% of pyrites cinders, 10–25% of silicic acid and 30–50% soda at about 700°C. and then heating it at a temperature not exceeding 1,000–1,100°. After cooling, mixture is granulated and hydrolysed with soft water for six hours at a temperature not exceeding 100°; the water may be acidified with hydrochloric acid.—*W. P. R.*

Base-Exchanging Resins. I. G. Farbenindustria A.-G. F. P. **816**: 448; Chem. Zbl. **2**: 3054 ('37). Base-exchanging resins may be prepared by condensing aromatic sulphonic acids with formaldehyde. For example, 175 grams *p*-phenol sulphonic acid and 40 grams of 30% formaldehyde are heated together for half an hour at 105°. A further 60 grams of formaldehyde are then added and the mixture is heated for 10 hrs. at 90°. A black resin is obtained. Sulphonic acids of resorcinol, purocatechol, naphthalene and phenanthrene may also be condensed with formaldehyde or the condensation products of formaldehyde and resorcinol or *m*-phenylenediamine may be sulphonated. The resins remove calcium oxide and can be used for the treatment of water.—*W. E. R.*

The Preparation by Ion-Exchange of a Pure Water Comparable with Distilled Water. *G.* Austerweil and A. Fiedler. C. R. Acad. Sci., (Paris) **205**: 1235 ('37). Water comparable with distilled water may be prepared by converting the salts present in natural water into the corresponding acids by passage through a base-exchange material containing exchangeable hydrogen ions. After removing free carbon dioxide, acids are eliminated by passage through substance with a basic reaction or an organic base, e.g. a quinonimine complex, which is insoluble in water both as a base and as a salt and can be regenerated by an alkaline solution. Traces of silica remaining in the water may be removed by filtration through activated alumina. Lignin which has been treated with concentrated sulphuric acid and washed may be used for the removal of the cations. Wool, fibre or horn, which have been washed with 1% sodium carbonate solution, or synthetic organic bases such as dyes may be used to remove the anions; action of the wool may be increased by esterifying its amino-acid constituents. The base-exchange material may be regenerated by treatment with dilute acid such as sulphuric or hydrochloric acid, and the material used for the removal of anions by a dilute base, such as sodium hy-

droxide or ammonia, in an amount slightly in excess of the theoretical.—*W. P. R.*

Methods of Preparing Pure Water. A. GUNTZ. J. Phys. Radium **8**: 4:47: ('37); Phys. Ber. **18**: 1699 ('37). A method of preparing distilled water is described whereby water with a specific resistance of 1×10^6 ohm per cm. may be obtained by a single distillation. Milk of lime, 1 gram of potassium or sodium persulphate, and a metallic catalyst to oxidise ammonia are added to the water, which is then boiled. A Jena glass filter is inserted in the path of the steam to condense and retain liquid. The heating is effected by an electric element immersed in the liquid. Other methods of treatment such as the electrolytic process and the method of B. A. Adams and E. L. Holmes, using the ion-exchanging properties of artificial resins, are discussed.—*W. P. R*

Determination of the Ammonia Content of Drinking Water. ALBERT HANSEN. Z. anal. Chem. **111**: 183 ('37). The standard methods used in the U. S. A., Germany and Austria are compared and criticized. A new method is described which was found to give excellent results in detg. 0.12–1.04 mg. NH_3 per liter. A series of standard solns. contg. known amts. of NH_4Cl is prepd. A blank is made by distg. 500 ml. of best water with 0.5 gram MgO, rejecting the first 200 ml. and collecting. Then 200 ml. of the water to be tested is added to the contents of the flask and best water added to about 400 ml. Then portions of distillate are collected in Nessler tubes. The color is matched, after adding Nessler's reagent, with standards and a titration made to see how much standard NH_4Cl soln. must be added to make the sample match the next higher standard. This procedure is preferred to the U. S A. method of using phosphate buffer of pH 7.4 instead of the MgO and using a large no. of Nessler tubes.—*C. A.*

A Simple Method for the Colorimetric Determination of Dissolved Oxygen. GEORGE GAD. Gas u. Wasser. **81**: 59 (Jan. 22, '38). A glass stoppered bottle of 50 ml. is filled carefully to the top with the water. Add a few crystals (about 0.05 gram) of ferroammonium sulfate (Mohr's salt) and a pellet (about 0.1 gram) of NaOH. Stopper immediately excluding any air bubble and shake until the sodium hydroxide is dissolved. Let the bottle stand a few minutes to settle the precipitate of iron hydroxide. Open and introduce with a pipette near the bottom of the bottle 3 ml. of concentrated HCl. Stopper again and shake. The acid solution is stable. Remove 2.0 ml. of the solution into a 100 ml. Nessler tube, add 3.0 ml. of 25% HCl, 90 ml. of distilled water then mix and add 5 ml. of a 10% potassium thiocyanide solution. The iron content is determined colorimetrically. The equation of the reaction $2\,FeO + O = Fe_2O_3$ shows that 79.9 parts Fe_2O_3 correspond to 8 parts O_2. The test does not claim high accuracy, but allows the test of small samples of water. Neither the iron content of the raw water nor its color influence the test.—*Max Suter.*

The Salles Teixeira Apparatus for Determining Natural Dissolved Gases in Mineral Spring Water. ANTONIO SALLES TEIXEIRA. Rev. brasil. chim. (São Paulo), **4**: 111 ('37). The water is placed in a flask, which may be heated,

and the flask connected to a bulb and gas buret in which a Torricellian vacuum is produced by lowering a mercury reservoir. Evolved gases are trapped in the bulb and then examined chemically and spectroscopically.—*R. E. Thompson.*

The Determination of Dissolved Nitrogen in Water. NORRIS W. RAKESTRAW AND VICTOR M. EMMEL. Ind. Eng. Chem.-Anal. Ed. **9**: 344 (Jul. '37). Dissolved gases are removed from 100 cc. water sample by repeatedly spraying in vacuum. After manometric measurement of gas evolved, oxygen is removed by reaction with phosphorus, volume measured, nitrogen removed by reaction with lithium, and volume of inert gas residue measured. Results for nitrogen on distilled water samples were slightly lower than accepted values but within 1%. In checking oxygen determinations by this method and that of Winkler, only in one case was discrepancy significantly beyond limits of error of the two methods. By closing sample bottles with stoppers carrying U-tubes partially filled with mercury, samples can be stored without allowing interchange of gases between water and atmosphere.—*Selma Gottlieb.*

Determination of Small Quantities of Oxygen in Gases and Liquids. I. J. W. MACHATTIE AND J. E. MACONACHIE. Ind. Eng. Chem.-Anal. Ed. **9**: 364 (Aug. '37). Oxygen in gaseous mixtures and dissolved in liquids can be determined by its reaction with copper wire wetted with ammonical solution of ammonium chloride. Copper oxidized is estimated colorimetrically by titrating blank to same copper-ammonia blue. Apparatus described gives accuracy of 3% with 0.02 to 2 ml. of oxygen. For liquids, sample containing about 0.1 ml. of oxygen is chosen. Other gases usually encountered do not interfere. Four determinations can be made per hour. With diagram.—*Selma Gottlieb.*

Rapid Method for Determining Free Sulfuric in Presence of Large Amounts of Ferrous Sulfate. L. KEBRICH. Chemist Analyst **27**: 7 (Jan. '38). Ordinary indicators not adapted to titration of free H_2SO_4 in presence of large amts. of $FeSO_4$. Method is described based on fact that when solns. of KF and $FeSO_4$ are mixed, Fe is pptd. at room temp. as FeF_2, which is stable in presence of dil. acids and alkalies. Free acid remains unchanged and may be titrated with $N/2$ KOH in usual way, using phenolphthalein as indicator. Fe^{+++} salts are also pptd. and do not interfere. Blank should be run on same vol. of the 50% KF soln. in CO_2-free water equal in vol. to Fe soln. taken for test. It is advisable to adjust KF soln. with KOH or dil. H_2SO_4 to near the neutral point, on acid side.—*R. E. Thompson.*

Rapid Determination of Calcium and Magnesium (in the Presence of Each Other). N. A. FREZE. Zavodskaya Lab., **6**: 756 ('37). To the filtrate from the ammonium hydroxide precipitation add an excess of potassium hydroxide and boil until all ammonium salts are decomposed. Evaporate to about 100 cc., add acid and make neutral to phenolphthalein. Heat to 70°C. and precipitate calcium with measured volume of 0.2 N potassium oxalate and then, without filtering, add measured volume of standard potassium hydroxide. Make up to definite volume, filter into a dry flask and, in an aliquot part of

filtrate, titrate excess potassium hydroxide with 0.1 *N* sulfuric acid to determine magnesium. Finally, to determine calcium, make acid with sulfuric acid and determine excess oxalate at 70°C. by titrating with potassium permanganate.—*R. E. Thompson.*

Determination of Magnesium in Limestone with 8-Hydroxy Quinolin. C. Franklin Miller. Chemist Analyst **27**: 11 (Jan. '38). Procedure for volumetric detn. of Mg in presence of much Ca is described in which Mg is pptd. by adding 8-hydroxy quinoline to soln. contg. Ca oxalate ppt., filtering off mixed ppt. in Gooch crucible, dissolving quinoline complex in strong HCl, adding excess standard bromate-bromide soln., followed by KI soln., and titrating liberated I with thiosulfate. Ca oxalate does not interfere. Method is accurate to at least 2%, which is better than with usual phosphate recovery unless elaborate precautions are observed.—*R. E. Thompson.*

Determination of Magnesium. F. Rogoziński. Bull. intern. acad. polon. sci., Classe sci. math. nat. '37A, 477 (in French). After the ppt. of $MgNH_4PO_4 \cdot 6H_2O$ is washed with dil NH_4OH, it can be washed with acetone and weighed with its water of crystn. To det. very small quantities of Mg., it is recommended to ppt. as $MgNH_4PO_4 \cdot 6H_2O$, dissolve ppt. in acid, ppt. the P with NH_4 molybdate and weigh the yellow ppt. On assumption that ppt. is $(NH_4)_3PO_4 \cdot 14MoO_3$ and that 89 mg. of ppt. corresponds to 1 mg. of Mg, fairly accurate results were obtained.—*R. E. Thompson.*

Titration of Carbonates. A. F. Kitching. Analyst, **62**: 664 ('37). When a soluble carbonate is titrated with dilute acid, the indicator usually gives the "acid" color before the end point is reached and after brief pause the "alkaline" color returns. This is probably caused by time required for reaction between carbon dioxide and water to reach equilibrium. Indicators such as bromocresol purple and bromothymol blue show this phenomenon as well as the older ones like methyl orange.—*R. E. Thompson.*

Determination of Chlorides and Bromides. L. A. Reber and Wallace M. McNabb. Ind. Eng. Chem.—Anal Ed. **9**: 529 (Nov. '37). Chloride or bromide may be detd. by pptg. with excess of 0.1 *N* $AgNo_3$ in presence of HNO_3, and titrating excess Ag in filtrate with 0.1 *N* KI using starch soln. and ceric ammonium sulfate as indicators. Satisfactory agreement with Volhard and gravimetric methods was obtd. using .03658 *N* KCl and .08 *N* KBr. Procedure is also applicable to iodides. Advantages of method lie in stability and ease of prepn. of standard solns. used.—*Selma Gottlieb*

Determination of Barium, Sulfur, and Sulfates. Stephen J. Kochor. Ind. Eng. Chem.-Anal. Ed. **9**: 331 (Jul. '37). Directions are given for avoiding interference of other ions in determination of barium or sulfate, using an oxyquinone derivative (tetrahydroxyquinone or dioxy-diquinone) as indicator on test paper. Sulfate is precipitated with excess of standard barium chloride and titrated back with standard sodium sulfate to endpoint in buffered alkaline solution. Barium is titrated directly with sodium sulfate. Satisfactory agreement with gravimetric methods was found.—*Selma Gottlieb.*

Quantitative Determination of Aluminum by Precipitation with Urea. HOBART H. WILLARD AND NING KANG TANG. Ind. Eng. Chem.-Anal. Ed. 9: 357 (Aug. '37). When a solution containing aluminum and succinic acid is gently boiled for one to two hours with urea and ammonium chloride, dense precipitate of aluminum succinate is obtained. Aluminum is estimated by ignition of precipitate to aluminum oxide. Accuracy is far superior to that obtained by precipitation with ammonium hydroxide, since precipitate is dense, and readily filtered and washed. Hydrolysis of urea gives slow, uniform increase in pH (to pH 4.2–4.6), reaction occurs in homogeneous solution, and final pH is low. Separation of small amounts of aluminum from large amounts of other metals by one precipitation is superior to ammonia method.—*Selma Gottlieb.*

Limitations of the Phenol Coefficient. GEORGE F. REDDISH. Ind. Eng. Chem. **29**: 1044 (Sep. '37). Phenol coefficient test was developed for testing germicidal properties of phenol-like disinfectants and should not be used for testing antiseptics, substances insoluble in water or substances not akin to phenol in composition or action. It is not suitable, e.g., for testing chlorine or chlorine compounds, which are adversely affected in germicidal activity by organic matter. Special methods (e.g., varying type of test organism) and determination of efficacy of antiseptics are discussed.—*Selma Gottlieb.*

Absorption of Carbon Dioxide. D. H. KILLEFFER. Ind. Eng. Chem. **29**: 1293 (Nov. '37). Experiments on absorption of CO_2 by solns. contg. both Na_2CO_3 and $NaHCO_3$, alone and in presence of various known surface tension depressors, suggest that surface tension may be an important factor in detg. rate of reaction.—*Selma Gottlieb.*

Intensity and Stability of Ferric Thiocyanate Color. H. W. WINSOR. Ind. Eng. Chem.–Anal. Ed. **9**: 453 (Oct. '37). In 2-methoxyethanol (ME) as solvent, ferric ion gives red thiocyanate color 85% more intense than in water. (ME) is colorless, almost odorless, miscible with water in all proportions, dissolves ammonium thiocyanate readily, is easily purified by distn., and is economical because of low price and low volatility. For routine analysis, pipet 2 ml. of unknown soln. into 10 ml. vol. flask, add 2 drops of 0.1 *N* potassium permanganate, and when decolorized fill to mark with reagent contg. 10 grams NH_4CNS in (ME) to make 250 ml. Standards are similarly treated. HCl concn. should be 2.5 *N* and iron standard should contain 0.02 mg. of iron per ml. Colors are compared in colorimeter.—*Selma Gottlieb.*

The Stability of Solid Sodium Thiosulfate. VICTOR K. LA MER AND HAZEL M. TOMLINSON. Ind. Eng. Chem.—Anal. Ed. **9**: 588 (Dec. '37). Tests showed that solid $Na_2S_2O_3$ decomposes slowly to sulfur and some substance giving analytical reactions for sodium sulfite. Recrystg. removes contaminants. Decomposition is slow and not readily detected in analytical use. Deterioration of solns. of freshly recrystd. $Na_2S_2O_3$ is not more rapid than that of solns. from samples not recently recrystd.—*Selma Gottlieb.*

Standardizing Silver Nitrate Volumetric Solution. ROBERT D'ORAZIO. Ind. Eng. Chem.—Anal. Ed. **10**: 23 (Jan. '38). $AgNO_3$ can be indirectly stand-

ardized against standard NaOH soln. by titrating alkali with un-standardized HCl using phenolphthalein as indicator and using resulting neutral NaCl soln. for titration of $AgNO_3$ with potassium chromate as indicator. Same principle can be applied to standardization of $KMnO_4$ or oxalic acid solns., first neutralizing oxalic acid with standard NaOH in presence of non-reducing indicator, and then titrating resulting soln. with $KMnO_4$.—*Selma Gottlieb.*

Purification of Graphite for Spectrochemical Analysis. A. H. STAUD AND A. E. RUEHLE. Ind. Eng. Chem.—Anal. Ed. **10:** 59 (Feb. '38). Graphite of fairly high purity is cut into desired form for use as electrodes in spectrochemical analysis, heated to redness in silica dish over oxy-gas burner, cooled, refluxed with 1:1 H_2SO_4 for 24 hrs., washed and boiled with water repeatedly to remove all acid, and heated as before. Purified product is cooled and stored in capped bottles.—*Selma Gottlieb.*

BACTERIOLOGY

Notes on the History of Bacteriology. The Introduction of Agar-Agar into Bacteriology. ARTHUR PARKER HITCHENS AND MORRIS C. LEIKIND. J. Bact. **35:** 21 (Jan. '38). Agar-agar was introduced into bacteriology by Frau Fanny Eilshemius Hesse, wife of Dr. Walther Hesse, a district physician, of Schwarzenberg, Saxony. Although no exact date is ascertainable, agar was first used sometime during the early 1880's. Frau Hesse, assisting her husband in his studies on the bacterial content of air (begun in Koch's laboratory), suggested the use of agar as a solidifying agent to eliminate difficulties from using gelatin. The idea apparently came to Frau Hesse from her use of agar in making fruit jellies. She received the recipe from her mother who, in turn, had received it from a Dutch family; they had brought it from Batavia in the Dutch E. Indies, before coming to America. When agar was found to be successful in Dr. Hesse's experiments, he communicated the discovery to Robert Koch. Koch recognized the value of this and adopted its use in his laboratory. No formal paper was ever published on this discovery. Frau Hesse of German (Hanover) descent was born in Jersey City, N. J., in 1850. She met her husband while travelling in Germany and spent the rest of her life there. She died in '34, in Dresden.—*Ralph E. Noble.*

Studies of Freshwater Bacteria. IV. Seasonal Fluctuations of Lake Bacteria in Relation to Plankton Production. ARTHUR T. HENRICI. J. Bact. **35:** 129 (Feb. '38). The quantity of total net plankton, plate counts of bacteria in the water, and microscopic counts of periphytic bacteria have been determined in a shallow, unstratified lake of the seepage type, during a drought year when the lake received no surface drainage. Under these conditions it was found that the numbers of bacteria, as estimated by both methods, followed closely the curve for total plankton, with a lag which was greater in case of the plate counts. It is concluded that production of organic matter by plankton organisms is an important factor in determining the number of bacteria in the water. Microscopic and plate counts of bacteria in the concentrated net plankton did not appear to fluctuate significantly through the seasons.—*Ralph. E. Noble.*

Hydrogen Sulfide Studies. I. Detection of Hydrogen Sulfide in Cultures. CHARLES A. HUNTER AND H. GILBERT CRECELIUS. J. Bact. **35**: 185 (Feb. '38). Exps. to determine the sensitivity of ferric ammonium citrate and bismuth (Bi) liquor for detecting hydrogen sulfide (H_2S) definitely show the superiority of Bi over iron (Fe) irrespective of the pH. The most sensitive range of Fe is in an alk. menstruum while with Bi the pH conc. has no effect. After experimenting with more than 650 mediums, incorporating a soluble form of Bi, 0.5% Bi liquor or 16 mg. Bi and ammonium citrate, Merck, U.S.P. IX, several formulas were developed which give good results. The variable factor is the tryptone, not all lots being of uniform composition. In case pptn. occurs with certain lots of tryptone the addition of 5% of skim. milk overcomes this difficulty. The bismuth sulfite $(Bi_2SO_3)_2$ medium is far superior to any incorporating lead or Fe for detection of H_2S in cultures. Results show that organisms producing a small quantity of H_2S give neg. results with Fe while in the $Bi_2(SO_3)_2$ medium definite browning occurs. Organisms which are usually stated in the literature to be neg. H_2S formers, such as *Salmonella paratyphi* and *Shigella dysenteriae*, give pos. reactions with Bi. It is recommended that the indicator and method be stated when recording whether an org. does not form H_2S. It is not sufficient to state that the org. is a neg. or pos. H_2S producer.—*Ralph E. Noble.*

Comparative Studies of Methods for the Detection of Hydrogen Sulfide in the Coli-Aerogenes Group. CHARLES A. HUNTER AND JAMES E. WEISS. J. Bact. **35**: 20 (Jan. '38). Ability of the coli-aerogenes group to produce hydrogen sulfide was studied, using 152 strains. 98 cultures were isolated from water supplies, 35 from human feces and 19 were stock cultures. The cultures were classified into 3 groups: *Escherichia coli*, *Aerobacter aerogenes* and "intermediates." Methods for detecting formation of hydrogen sulfide were: Difco lead acetate, Difco peptone iron, semi-solid peptone iron (0.5% agar), semi-solid bismuth mannitol agar (Hunter and Crecelius) and bismuth filter paper. Of the 78 cultures of *Escherichia coli*, only 2 gave a positive reaction in the lead acetate and peptone iron media, but in the bismuth medium all 78 were positive, and with bismuth paper 57 were positive. With the 16 aerogenes strains no hydrogen sulfide was formed in the lead acetate or peptone iron media, while all strains were positive in the bismuth medium and 12 gave positive reactions with bismuth paper. There were 57 cultures classified as intermediates," of which 19 were positive in the lead and iron media and 56 positive with semi-solid bismuth mannitol agar. The bismuth paper showed that 34 cultures produced hydrogen sulfide. Semi-solid peptone iron medium failed to show any increase in number of positive reactions and did not prove as satisfactory as the usual 1.5% agar. These results show that practically all members of the coli-aerogenes group produce hydrogen sulfide, when tested with a sensitive indicator, the only differences in the organisms being the quantity of hydrogen sulfide produced.—*Ralph E. Noble.*

Nitrogen Availability as an Aid in Differentiation of Bacteria in the Coli-Aerogenes Group. N. B. MITCHELL AND MAX LEVINE. J. Bact. **35**: 19 (Jan. '38). The availability of nucleic acid nitrogen and certain of its degra-

dation products for the coli-aerogenes group of bacteria was investigated. The purpose was to secure an approach, other than by carbohydrate studies, to the systematic and physiological relationships of organisms comprising this group. Previous work on uric acid suggested the possibility of employing purines. The compounds tested included yeast nucleic acid, xanthine, adenine sulfate, uric acid, uracil, allantoin, hydantoin and urea. Over 350 coli-aerogenes strains were used. This collection was considered representative of the *Escherichia, Aerobacter* and "intermediate" groups. Xanthine and adenine were attacked by all strains, and consequently had no differential value. *Aerobacter* strains utilized nitrogen of all the other compounds, whereas the *Escherichia* and "intermediate" strains were each able to utilize nitrogen of only one compound. Uracil was an available nitrogen source for *Escherichia*, but not for "intermediate" strains. Urea was an available nitrogen source for "intermediate," but not for *Escherichia* strains. These data, when correlated with the results of Voges-Proskauer, citrate, hydrogen sulfide, and indol tests, strengthen the evidence for allocating the "intermediate" strains to a separate genus, *Citrobacter*. About 90% of the "intermediates" gave reactions identical with those of a transfer of the original strain, *Citrobacteria freundii*, the type species of the genus *Citrobacter*.—*Ralph E. Noble.*

The Fermentation of Acetyl-Methyl-Carbinol by the Escherichia-Aerobacter Group and Its Significance in the Voges-Proskauer Reaction. RALPH P. TITTSLER. J. Bact. **35**: 157 (Feb. '38). The ability to ferment acetyl-methyl-carbinol has been determined for 175 strains of the *Escherichia-Aerobacter* group. Approx. one-half the strains of *Aerobacter aerogenes* and *Aerobacter oxytocum* fermented this substance, but it was not attacked by any of the strains of *Aerobacter cloacae, Aerobacter levans*, or by any of the members of either the *Escherichia* genus or the *Escherichia-Aerobacter* "intermediate" group. Every strain which fermented acetyl-methyl-carbinol also grew and produced acid in a synthetic medium containing acetyl-methyl-carbinol as the sole source of carbon. These also gave neg. Voges-Proskauer reactions in Clark and Lubs' medium, when the cultures were incubated for periods exceeding 3 to 5 days. Cultures of the *Escherichia-Aerobacter* group to be tested for acetyl-methyl-carbinol should not be more than 2 days old. Relation of acetyl-methyl-carbinol to flavor of certain foods is discussed.—*Ralph E. Noble.*

A Study of the Paracoli Group. JACOB L. STOKES, R. H. WEAVER AND M. SCHERAGO. J. Bact. **35**: 30 (Jan. '38). Thirty-two strains of the paracoli group were isolated from human feces and their morphological and biochemical characteristics were studied. All strains produced some degree of lactose fermentation on continued cultivation in 5% lactose broth. From 22 strains, variants were obtained that were able to ferment 1% lactose broth within 48 hrs., with acid and gas production. These variants, therefore, were indistinguishable from members of the coli-aerogenes group. It is concluded that the strains of the paracoli group studied are variants of various members of the coli-aerogenes group. On the basis of methyl-red, Voges-Proskauer and sodium citrate tests, 30 strains appear to be variants of members of the *Es-*

cherichia genus and 2, variants of members of the coli-aerogenes "intermediate" group.—*Ralph E. Noble.*

The Possibility of Change in the Lactose-Fermenting Power of Colon Bacilli. W. MINNING. Zentr. Bakt. Parasitenk., I Abt., Orig. **140**: 23 ('37). Colorless (non-lactose fermenting) colonies on Endo medium acquired power to ferment lactose in liquid media within 24 hrs., after 8 passages in liquid lactose media, and they gave typical colon reactions. They did not acquire lactose-fermenting power during 21 passages through peptone water.—*R. E. Thompson.*

Application of Silica Gel Nutrient Medium to the Investigation of Water and Sewage. H. O. HETTCHE AND H. MÜNCH. Arch. Hyg. Bakt. **119**: 168 ('37). An easily prepd. nutrient medium is described in which SiO_2 gel replaces agar. The medium is superior to agar in the following respects: (a) soln. and filtration are unnecessary, (b) injury to the bacteria by high temps. is avoided, (c) redissolving with consequent change in pH is unnecessary, (d) the medium is well buffered with PO_4 and (e) the medium is easily and economically prepd. Indicators can be used with this medium but are more easily read than with agar.—*C. A.*

A Modified Eijkman Medium for the Isolation of Escherichia Coli from Sewage. A. A. HAJNA AND C. A. PERRY. Sew. Wks. J. **10**: 261 (Mar. '38). The substitution of lactose for dextrose in the authors' Eijkman medium resulted in the recovery of more *Esch. coli* from sewage, while the addition of 0.1% of sodium formate decreased the efficiency of the lactose medium.—*Arthur P. Miller.*

Improved Counting Plate for Bacteria Colony Counts. ROGER C. HIGGINS. Chemist Analyst **27**: 21 (Jan. '38). Staining of Jeffers plates a rich brown color with $KMnO_4$ soln. facilitates counting of colonies on agar plates.—*R. E. Thompson.*

STERILIZATION

The Presence of Nitrites in Water and their Effects on Sterilization by Chlorine. M. ETRILLARD AND LAMBERT. Rev. Microbiol. Appliquée (Fr.) **3**: 189 ('37). Among the various tests of the quality of water is one which measures the amount of free chlorine which is absorbed during a given time, and this test has an important bearing on the sterilization of water. The result of the test varies for each water, depending upon its chemical composition, more especially upon the dissolved substances which chlorine is capable of oxidizing. Among these dissolved substances the part played by nitrites has not hitherto received sufficient attention and the authors, who are engaged upon the examination of the Paris water supply, have shown that nitrites clearly retard the bactericidal action of chlorine. The experiments described relate to both unfiltered and filtered waters in which the chlorine absorption has been carefully measured and the waters were inoculated with *Bact. coli* and chlorinated. The *Bact. coli* content of the chlorinated water was

estimated at intervals of 10 minutes for half an hour. There was in all cases residual chlorine at the end of half an hour, but the results of the tests show definitely that the presence of nitrite interferes with the sterilizing action of the chlorine.—*B. H.*

Some Factors Affecting the Germicidal Efficiency of Hypochlorite Solutions. A. S. RUDOLPH AND MAX LEVINE. J. Bact. **35:** 3 (Jan. '38). Studies were made of the comparative germicidal efficiency of hypochlorite solutions containing 25, 100, and 500 p.p.m. available chlorine at constant temp. and initial reaction (pH). The effects of pH and temp. were studied by using hypochlorite solutions containing 25 p.p.m. available Cl_2 and varying either the pH or temp., keeping all other factors constant. To 100-cc. portions of various hypochlorite solutions, contained in two-necked flasks held in a water bath at the desired temp., was added 1 cc. of a freshly prepared suspension of *Bacillus metiens* spores. At appropriate intervals, 5 cc. of the spore-hypochlorite mixture was transferred to 45 cc. of sterile distilled water, containing slightly more than enough sodium thiosulfate to neutralize the Cl_2 carried over. Dilutions were made and plated on standard nutrient agar. Counts were made after 24-hrs. incubation at 30°C. Results show that increasing the conc. of available Cl_2 four-fold reduces the killing time about one-half. Changes in pH affect the germicidal power of hypochlorite solutions to a much greater extent than do changes in conc. of available Cl_2, the germicidal power decreasing with decreasing pH. Germicidal efficiency increased with rising temps. Killing time was reduced 50–75% for a rise of 10°C.—*Ralph E. Noble.*

The Handling and Feeding of Chlorine at the Jamaica, N. Y. Screening Plant. G. E. HENKEL. Sew. Wks. J. **10:** 311 (Mar. '38). Average flow at the Jamaica, N. Y., screening plant is 33 m.g.d. Chlorination of the sewage is accomplished by 5 chlorinators having a total capacity of 4550 lb. per 24 hr. A chlorine residual of between 0.5 and 1.0 p.p.m. is maintained. Description of the use and effectiveness of pressure reducing valves in connection with the supplying of chlorine from the supply tanks to the chlorinators is given.—*Arthur P. Miller.*

On the Determination of the Free Chlorine in Drinking Water. KARL HEINZ TANZLER. Gas-u. Wasser. **81:** 24 (Jan. 8, '38). Satisfactory water should be produced if possible without chemical additions. Recourse to chlorination should only be had if the danger of infection cannot be eliminated otherwise. Chlorine can be applied in many forms such as hypochlorous acid HOCl or as the following: chlorinated lime, calcium hypochlorite, magnesium hypochlorite, and sodium hypochlorite. The action of chlorine on ammonia produces chloramines. Of the organic amines, p-toluolsulfo-chloramidsodium ($H_3C \cdot C_6H_4 \cdot SO_2 \cdot NClNa$) is used in tablet form, as it produces NaOCl on solution in water. The most common form for chlorination is liquid chlorine. Some of the chlorine added to the water is used up. The control of the effectiveness of the chlorination is by bacteriological tests and by determining the residual chlorine, which should be 0.15 to 0.25 p.p.m. Four methods of de-

termination for such small amounts of chlorine are discussed. 1. The use of starch-potassium iodide is also influenced by iron, manganese and many oxides of nitrogen. Better and more stable is a starch-zinc iodide solution although this solution has to be kept from cold. 2. The use of benzidin requires a very definite pH value, yet even so the color change is not very uniform. 3. The determination with ortho-tolidine should be made at temperatures above +10°C. and away from direct sunlight. Iron and manganese give the same color, a color which varies with the time. 4. Dimethyl-p-phenylendiamin is also sensitive to iron and manganese even if made up with phosphoric acid. Nitrites also influence this reagent whose color changes with time and temperature. All the methods therefore show errors in the determination of the free chlorine. For large chlorine amounts (over 0.3 p.p.m.) the potassium iodide or zinc iodide method is recommended, for small amounts the benzidine or ortho-tolidine method.—*Max Suter.*

Destruction of Pathogenic Germs in Drinking Water by Tartaric Acid Without and With Subsequent Neutralization. H. VIOLLE. Presse med. **45**: 1355 ('37). A 0.35% soln. of tartaric acid in distd. H_2O kills *Eberthella typhosa* within 20–30 min., *B. dysenteriae* Shiga in 2 hrs. and *Vibrio cholerae* in 10 min. *Escherichia coli* shows in 0.4% soln. a prompt reduction in no. but some germs survive 48 hrs. The alky. of common drinking water reduces the acidity not more than 10%. For practical purpose, the acid may be neutralized with $NaHCO_3$ after the free acid brought about sterilization.—*C. A.*

Experimental Investigations in Connection with the Action of Catadyn Water on Bacteria. L. SCHIOPPA. Ann. Igiene (sper.) **46**: 11: 497 ('37); Chim. et Industr. **38**: 886 ('37). Water which has been treated by the Catadyn process and contains small quantities of silver inhibits the development of bacteria. The inhibiting action increases with the degree of activation of the water, reaches a maximum with a silver content of about 260γ per liter and does not increase further even with silver contents of 300, 400 or 800γ. At least one to two hours are necessary for the inhibiting action to become bactericidal. This time does not depend on the amount of silver present in the polluted liquid. No appreciable difference has been observed in the behaviour of mobile and immobile bacteria when subjected to the action of Catadyn water. The number of bacteria appears to affect the mechanism of disinfection but only when it exceeds a limit which can be estimated at about 100,000 per cc.; a retardation of the bactericidal action is then observed but the cause is still not clear.—*W. P. R.*

Experimental Study of the Disinfecting Power of Catadynized Water Toward Foodstuffs (Vegetables, Fruit, Mollusks). P. E. PERINI. Ann. Igiene **46**: 505 ('36); Chimie & industrie **39**: 152. The disinfecting action toward *B. coli* is certain, but requires a sufficient time of contact between the catadynized water and the foodstuffs. With oysters disinfection is complete in 8 hrs. and, contrary to Cl antiseptics, does not affect the taste and other organoleptic properties. With fruit and vegetables (salads) 4 hrs.' contact is generally

sufficient to ensure complete destruction of pathogenic germs. The water used contained 260 γ of Ag per liter. The no. of organisms decreases rapidly: with a salad which contained originally 40,000 to 50,000, the values after 1, 2, 3 and 4 hrs.' treatment were 30,000, 15,000, 1,600 and 300, resp.—*C. A.*

FILTRATION

Water Filtration During 1937. ANON. Pub. Wks. **69**: 1: 13 (Jan. '38). Summary of new ideas and developments in '37 as taken from magazine section known as "Water Wheel." Present practice calls for filter sand of 0.40 mm. and 0.55 mm. effective size with some tendency to use even larger sizes if conditions permit. "Permeability" of filter sand is a function of the viscosity of the liquid and the porosity, shape and graduation of the granular material. Varies inversely as the viscosity of the water; as the 6th power of the porosity for angular Iowa river sand and as the 5th power for rounded Ottawa sand; and as the square of the diam. of sand grains; was 50% greater for standard Ottawa sand than for angular Iowa river sand of same grain sizes and porosities. Gravel satisfactory for filters is becoming scarce. In 4 mo. comparative tests between sand and anthracite beds wash water used in coal beds was 27% less in one case and 42% less in another case. Rate of applying wash water should increase as sand size and water temp. increase. Chief cause of filter bed troubles is incomplete cleansing of sand, may cause shrinking, cracks and mud balls. Surface washing of sand practical means of keeping sand beds clean, such systems use from 2 to 8 g.p.m. per sq. ft. sand area depending on clogging tendency, 3 to 4 g.p.m. good av. Some results with sub-surface filtration have been reported at Toledo, Ohio stating desirability of system will no doubt be detnd. by comparative cost, difficulty of expanding plant when necessary, and whether added capacity by this means is justified at the possible expense of slightly increased effluent turb. for short periods. Several slow sand filter installations with provision for chem. coag. were finished during yr.—*Martin E. Flentje.*

Gravity Filters—Coagulants Used. ANON. W. W. Inf. Exch., Canadian Sect., A.W.W.A. **2**: A:4:20 (Feb. '38). Coagulation data for plants in Canada are given, including coagulant used, feed equipment (no. of units, date installed, type, manufacturer, and capacity), point of application, pounds used in '35 and av. dosage based on water consumption in '35. Of 66 plants reported as employing coagulants, alum used at 65 and aluminoferric at 1. In addition to alum, ferrous sulfate and lime added at 1 plant, lime at 6 and soda ash at 3. Of 65 plants, 24 employ dry feed, 39 solution feed and 2 both types. Capacity (data incomplete) varies from 3 to 3000 lbs. per hr. Av. alum dosage (also incomplete), disregarding periods during which no coagulant was applied, varied from 0.076 to 7 g.p.g. (Imp.), ferrous sulfate 2.9 (also 3.0 g.p.g. of alum at this plant), lime 0.5 to 2.4 and soda ash 0.94 to 3.6.—*R. E. Thompson.*

Gravity Filters—Sand, Gravel and Controllers. ANON. W. W. Inf. Exch. Canadian Sect., A.W.W.A. **2**: A: 3: 16 (Jan. '38). Data given on 70 rapid sand filter plants in Canada, including total sand area, depth and size of sand, source

of sand, depth and size of gravel, and no., kind and location of rate controllers. Sand depth reported for 65 plants as follows: 18″ at 2 plants, 24–26″ at 9, 27–30″ at 46, 32–36″ at 6, 54″ at 1 and 9′ at 1 (drifting sand filters, Toronto). Effective size varies from 0.35 to 0.6 mm. and unif. coeff. from 1.3 to 2.0. Gravel depth, reported for 63 plants, varies from 9 to 27″, as follows: <12″ at 4 plants, 12″ at 16, 12 to 18″ at 12, 18″ at 22 and > 18″ at 9. No. of sizes of gravel varies from 2 to 7; largest size gravel from $\frac{3}{4}$″ to 2$\frac{1}{2}$″ and smallest from 1 mm. to $\frac{5}{16}$″. Rate controllers used at 58 plants, located in practically every instance at outlet.—*R. E. Thompson.*

New Rapid Filters at Brisbane, Australia. Wtr. and Wtr. Eng. (Br.) **39:** 218 ('37). Six enclosed rapid-flow filters recently installed at Brisbane have a capacity of 12 mil. gal. of water per day. When the hydraulic resistance in any filter rises to a predetermined value, the supply of water to the filter is automatically shut off and the medium is washed by water at high pressure flowing in the reverse direction.—*W. P. R.*

Flow in Filter Layers. WALTER BÜCHE. Z. Ver. deut. Ing., Beiheft Verfahrenstech. '37: 155. Rate of filtration through a porous layer, which depends on relation between weight of column of liquid, friction coef. and pore size, is given math. expression. Deviations from the equation, termed filter effect, always reduce the rate. Effect can be explained by evolution of dissolved gas or by vaporization. Latter leads to steady state in which amount passed through filter is independent of resistance of filter. Mehner's thesis is reviewed and applied successfully to filtration of water through sintered glass plate and through a tube of sand.—*R. E. Thompson.*

CORROSION AND CORROSION CONTROL

Development and Use of Spun Bituminous Coatings for Water Pipe in the U. S. GEORGE E. BOYD. J. N. E. W. W. A. **51:** 393 (Dec. '37). In '21 it was estimated the 138,000 mi. of gas lines and 110,000 mi. of oil lines in U. S. suffered from soil corrosion to extent of 100 million dollars per yr. This enormous loss led to development of more efficient protective coatings of which coal tar enamels show superior qualities to any other. Cold coatings such as paints, emulsions and inhibitors are worthless for prevention of underground corrosion; greases do not prevent corrosion but do somewhat reduce pitting, but are not good if cathodic protection is used; hot coal tar enamels (heavy coal tar products containing certain proportion of inert mineral fillers to give structural strength) are generally best types of protection. Spun bituminous linings now being universally used with aggressive waters. All of common difficulties with this type of lining can be eliminated by proper supervision on part of foundry. Examples are given of success with this type of coating and methods of application described.—*Martin E. Flentje.*

Development and Use of Spun Bituminous Coating for Water Pipe in Great Britain. J. MITCHELL. J. N. E. W. W. A. **51:** 390 (Dec. '37). To meet the needs of steel pipe linings for consistent properties and desirability of re-

sisting unfavorable temp. effects British pipe mfrs. have adopted blown petroleum asphalt in preference to coal tar, resulting in much wider range of suitable physical properties and increased longevity of service. To get necessary thickness to protect pipe "Spun Bituminous Coating" was evolved and placed on market in '25. To apply the $\frac{3}{16}$" to $\frac{1}{4}$" thickness coating it is essential to eliminate all mill scale as coating must be applied to a bare metallic surface and surface must be warm so bituminous material will wet surface properly. To reduce cost a coating with min. of $\frac{1}{16}$" thickness is now also offered. Coating material containing filler used shows properties: melting point—220° to 240°F.; sp. gr.—1.2 to 1.4; penetration at 77°F., 100 grams, 5 sec.—13 to 15; penetration at 115°F., 50 grams, 5 sec.—20 to 25.—*Martin E. Flentje.*

Coating Steel Water Pipe by New Concrete Machine. C. P. HARNISH. W. Cons. News 13: 59 (Feb. '38). The requisites of a good concrete protective coating on pipe,—perfect bond between concrete and pipe, uniform and dense mix and inherent strength in coating, were met in a coating, mechanically placed, on an old 8", ½ mi. long steel pipe line. Accomplished by a small self-propelled patented machine which rode pipe, leaving behind finished concrete jacket. Pipe first cleaned by wire brushing. No forms required. Machine consists of a light steel rectangular frame which encompasses pipe supported on pipe itself by dollies. Upon frame is mounted a 3-h.p. gas engine driving a steel drum surrounding and concentric with pipe. On this drum are mounted curved steel arms forming throat or housing which forms the outside diam. of the concrete lining to be applied, in this case 1" larger in diam. than the pipe to be coated. Feeding hopper provided into which concrete was placed. In operation, arms revolve but do not touch pipe in annular space formed by pipe and housing. Feeding concrete into hopper forces concrete toward free outer ends of arms increasing pressure to point of compelling machine to back away and moving the machine along pipe. Mix used, 1 part cement, 1 sand and 2 roofing gravel, with 5 gal. water to 1 sack of cement. Rate of travel 6' to 8' per min. Finished coating presented an effective and workmanlike appearance, found to bond tightly to pipe and to be practically free from checks and cracks. Concrete coating then sprayed with asphaltic preparation for sealing and curing. Coating machine better suited to long transmission lines because it must be moved over cross connecting pipes.—*Martin E. Flentje.*

Neutralization of Corrosive Action. ROBERT SPURR WESTON. J. N. E. W. W. A. **51**: 384 (Dec. '37). Most natural waters attack metals appreciably, those most aggressive are high in CO_2 and low in protective organic and inorganic contents. Oxygen also factor in corrosion, as is pH. Treatment varies from corrective to protective, each water being separate problem. Aeration may be advantage with waters high in CO_2 disadvantage lies in introduction of oxygen. With low pH values, alkalies as soda and lime may be added. Lime best adapted because of film formed, addition should be controlled by equilibrium tests. Practically, equilibrium at one temp. only can be provided, necessary therefore to overdose and sometimes use other means, as sodium silicate, intermittently. Sodium silicate may be used to protect hot water

systems. No precipitation obtained in waters with silicate conc. of 0.10% if little or no calcium present. At Milford and Winchester, Mass. good results obtained by alternating lime and sodium silicate treatment. Ammonia-chlorine useful in maintaining carrying capacity of pipe lines, when tendency toward clogging with biological growths exists. Marble has been used as automatic contact medium, as well as solid sodium silicate and magnesite sand. Need for better automatic neutralizer led to German discovery of Magno-doublesalt containing MgO and $CaCO_3$ obtained by roasting dolomite. May be used in filter, quantity reqd. varying with water to be treated. Ordinary provisions are from 7000 to 9000 lbs. per mil. gal. daily cap. Involves loss of approx. 18.9 lbs. per mil. gal. per 1 p.p.m. CO_2. In water with av. content of 45 p.p.m. CO_2 and carbonate hardness of 85.6 p.p.m. use of material increased hardness 31.6 p.p.m. and removed all CO_2 giving phenol. alk. of 2-3.4 p.p.m.—*Martin E. Flentje.*

How Improved Equipment Can Help the Modern Distillery. L. P. WEINER. Chem. and Met. Eng. **44:** 710 (Dec. '37). While the basic processes have remained the same many changes have otherwise been made in the handling, storage and mfg. operations of the modern distillery. Among problems is control of corrosion of water and return condensate pipe lines. Reduction of oxygen to at least 1 cc. per liter necessary. Presence of CO_2 contributes to continued corrosion and effects of this phenomenon illustrated by several photographs.—*Martin E. Flentje.*

Treatment for the Prevention of Holder Discoloration. JOHN R. SKEEN AND A. L. WARD. Gas J., **219:** 537, 539, 541 ('37). In order to prevent the growth in gas holder water of organisms which would discolor the paint, search was made for materials which in solution in the water would create an unfavorable environment for the organisms. It was found that very small concentrations of sodium bichromate added to water in which specified pH is maintained by buffer solution of sodium bicarbonate will control the growth. Minimum permissible concentrations are 0.0024% for sodium bichromate and 0.03% for sodium bicarbonate. The treatment is effective even with enormous quantities of refuse in the water. It does not quite succeed in preventing growth of the very resistant iron bacterium, but this organism survives with difficulty in greatly modified form. The treatment also reduces corrosion of unpainted metal, other than that caused by stray currents, over 80%. The cost of treating 6 mil. gal. of water is about $1000. Paint capable of resisting the treated water must be employed.—*R. E. Thompson.*

The Corrosion Problem in Cambridge, Mass. MELVILLE C. WHIPPLE. J. N. E. W. W. A. **51:** 376 (Dec. '37). Experience with corrosion of various pipe materials is reviewed under several methods of treatment of Cambridge water. Impounding res. supply has analysis of: hardness 28 p.p.m.; alk., 15; color, 40; CO_2, 5; pH, 6.7. This water without treatment corrosive although not severely so; when used before purification plant constructed iron and steel plumbing had fairly short life, dezincification of brass pipe (mostly Muntz metal 60% Cu. and 40% Zn.) took place, such installations lasting, however,

for 10 to 20 yrs. Water after filtration and for first 6 mo. after purification plant started without pH correction, had following analysis: hardness, 28; alk., 5; CO_2, 7; pH, 6.0. Red water quite evident and action on brass accelerated. From Nov. '23 to Mar. '30 soda ash used for pH correction. Typical analysis then: hardness, 28; alk., 19; CO_2, 1.5; pH, 7.0. Severity of corrosion reduced but not satisfactorily so. 60-40 brass pipe showed continuous deterioration, in one case hot water caused failure within 3 yrs. due to dezincification. 67-33 brass showed deterioration in 5 yrs. but not to failure. 85-15 brass was subject to some corrosion with pitting over period of 3 yrs. Beginning Mar. '30 lime used to correct pH, amount gradually increased until '34 when sufficient added to saturate water with $CaCO_3$, with pH approx. 8.8. Cold water iron and steel lines now show distinctly less rust and soln. of Fe and less complaints of plumbing failures are received with both iron and brass pipe. Author believes, with present treatment, min. corrosion exists and that no more than mild action takes place on all brass (except possibly Muntz metal) and copper lines. Copper best suited for Cambridge water.—*Martin E. Flentje.*

HEALTH AND HYGIENE

The Cairo, Illinois, Swimming Pool. CHARLES M. ROOS. Pub. Wks. **68**: 12: 16 (Dec. '37). Municipal pool sponsored by various civic organizations and constructed with W. P. A. labor was opened June 3, '37. This and preceding pool has prevented former annual drowning of one or more children swimming in adjoining rivers. Adult section 100′ x 40′ x 9′ deep at one end and 3½′ at other, children's section 40′ x 15′ x 18″ to 24″ in depth. All water filtered.—*Martin E. Flentje.*

Fatal Poisoning During Welding with Dissolved Acetylene. R. MAENICKE. Arbeitsschutz '36, 283: Chimie & industrie **38**: 60. Death was due to acute pulmonary edema caused by nitrous gases formed by oxidation of atm. N in contact with the extremely hot flame. During welding in enclosed space, concn. of these gases can rapidly reach 0.828 mg. per liter, which is fatal in 30 min. During same operation, CO content can reach 42% by vol. Very active ventilation is essential in places where such operations are carried out.—*R. E. Thompson.*

Report on a Public Local Inquiry into an Outbreak of Typhoid Fever at Croydon in Oct. and Nov. 1937. Off. Cir. Br. W. W. Assn. **20**: 199 (Feb. '38). Reprint of a Ministry of Health report of an investigation into an outbreak of typhoid fever caused by water from well known as Addington Well supplying a high level area of Croydon, England. Well supplied 1 mil. gal. of the total of 6.066 mil. gal. normal yield of all wells. Croydon has area of 12,617 acres, 3,700 in high level area with pop. of between 36,000 and 40,000 of the 250,000 in Borough. Addington well constructed in 1888, is 10′ diam., 205′ deep, lined with brickwork to depth of 68′. Well has 2 long galleries or headings driven into chalk, one at depth of 151′ with length of 672 yds., and other 162′ below engine room floor and 150 yds. long. Epidemic probably caused by presence

of typhoid carrier among 18 workers in well during improvements on one of galleries during which time pressure filters were by-passed and no chlorine added. Conclusion reached that nothing dangerous about this well, that infection due to unfortunate and rare coincidence of 3 factors—(a) constructive changes in well, (b) presence of typhoid carrier, and (c) chlorination interruption. Total no. of cases and deaths not given.—*Martin E. Flentje.*

A Note on the Quality of Drinking Water on Trains. ARTHUR P. MILLER AND EDMUND C. GARTHE. U. S. Pub. Hlth. Repts. **53**: 300 (Feb. 25, '38). Bacteriological tests made on 1,090 samples of drinking water collected from containers on all types of cars operated by 9 different railroads having terminals in or adjacent to New York City indicated at least 2 of these railroads were inefficiently cleaning their storage containers or contaminating the water by handling it in a careless and insanitary fashion during the process of transfer from sources of supply to containers. One table included.—*R. E. Noble.*

The Spread of Tularemia Through Water, as a New Factor in its Epidemiology. S. P. KARPOFF AND N. I. ANTONOFF. J. Bact. **32**: 243 ('36). An outbreak of tularemia through drinking infected water from a brook in Russia is reported; hitherto it has been considered that the disease is spread only through contact with infected animals. The clinical symptoms of the disease are described. The presence of *B. tularense* in the water of the brook was shown in a series of laboratory tests on guinea-pigs.—*W. P. R.*

An Epidemic of Paratyphoid Fever with a Peculiar Source of Infection. J. CASPERSEN. Bul. of Hygiene (Br.) **13**: 106 (Feb. '38). Orig. abstr. from Norsk Mag. f. Laegevidenskapen **98**: 138 ('37). Epidemiological data given for epidemic of paratyphoid fever in Norwegian town. Traced conclusively to infection from a dog. Notes that paratyphoid has not hitherto been demonstrated in dogs, but concludes that in such epidemics the possibility must be entertained of an infection from dogs when searching for the original source of infection.—*P. S. Wilson.*

Waterborne Disease. (Some Random Notes). A. H. WADDINGTON. Wtr. and Wtr. Eng. (Br.) **40**: 87 (Mar. '38). While it is commonplace to describe water as one of the purest products supplied on a large scale to the general public at a low cost, it is also commonplace to say that in Nature there is no such thing as pure water. Only constant vigilance can ensure freedom from outbreaks of waterborne disease. Considered unwise to depend on single method of purification and in control of waterborne disease 3 factors to be considered,—(1) control of raw water quality; (2) purification of raw water; (3) prevention of contamination of purified supply. Pointed out that knowledge of problems of impounded or abstracted water and combined biological and bio-chemical changes that take place is incomplete, considerable study however being given to problem. Water before final sterilization should be of satisfactory quality, in any treatment plant failure of one unit of purification process should not jeopardize safety of the supply. Streeter's limits of pollution cited. Such illnesses as typhoid and paratyphoid fever, dysentery,

gastro-enteritis, leptospiral jaundice, dental fluorosis, etc. can all be caused by water. Article closes with 2 quoted paragraphs from Sir Alexander Houston, last one being,—"The goal of safety lies in not introducing any new factor in waterworks' procedure which does not bear the hall-mark of epidemiological approval, and in so safeguarding a finely purified water that the entrance of any adventitious water into the supply is absolutely impossible."—*Martin E. Flentje.*

WATER RATES

6 Per Cent Utility Profit Held Sufficient. ANON. Eng. News-Rec. **120**: 558 (Apr. 21, '38). In opinion handed down Apr. 13 denying an appeal of Arkansas-Louisiana Gas Co. of Texarkana, Ark., which sought increase in rates, U. S. Circuit Court of Appeals for the eighth circuit held that under present economic conditions 6% on its investment is fair return for public utilities. Company had contended that it was entitled to return of 10% on production facilities and 8% on transportation and distribution facilities. The Appeals Court opinion quoted Chief Justice Hughes of U. S. Supreme Court, who wrote that a public utility is entitled to rates which will permit it to earn a return equal to that from other investments attended by same risks and uncertainties but has no right to profits such as are realized or anticipated on highly profitable or speculative ventures.—*R. E. Thompson.*

Meter Rentals. ANON. W. W. Inf. Exch., Canadian Sect., A. W. W. A. **2**: B: 1: 1 (Feb. '38). Tabulation of 126 municipalities in Canada is given showing the annual meter rental charges for installations of various sizes. Data are too extensive to be abstracted. Frequency of billing is included (see following abstract).—*R. E. Thompson.*

Metered Water Rates. ANON. W. W. Inf. Exch., Canadian Sect., A. W. W. A. **2**: B:2:6 (Feb. '38). Data given regarding meter rates in Canadian municipalities, together with frequency of billing, discounts allowed and unit of measurement used. Of 109 communities for which billing frequency is given, period is 1 mo. in 20, 2 mo. in 18, 3 mo. in 63, 4 mo. in 1, 6 mo. in 3 and 12 mo. in 4. Discounts allowed in 53 municipalities, as follows: 5% in 2, 10% in 40, 15% in 2 and 20% in 5: in other 4 the discount varies. Of 101 communities for which the unit of measurement is reported, 37 employ cu. ft. and 64 employ gallons. For rate data, the original must be consulted.—*R. E. Thompson.*